LA-UR-97-2066

- FINAL DATA REPORT FOR DRAFT SPD EIS -

RESPONSE TO THE

Surplus Plutonium Disposition Environmental Impact Statement

DATA CALL

FOR A MIXED OXIDE FUEL FABRICATION FACILITY

LOCATED AT THE

SAVANNAH RIVER SITE

in support of the

US DEPARTMENT OF ENERGY

Fissile Material Disposition Program

Prepared by the

Technology and Safety Assessment Division

of the

LOS ALAMOS NATIONAL LABORATORY

Rev. 3, June 22, 1998

EXECUTIVE SUMMARY

This document is one of four that comprise revision 3 of the data reports which have been prepared in response to the Surplus Plutonium Disposition (SPD) Mixed Oxide (MOX) Fuel Fabrication Facility (FFF) Environmental Impact Statement (EIS) Data Call. These reports are being issued, in conjunction with the draft EIS, for public review and comment. The reports have been prepared by staff and contractors of the Technology and Safety Assessment (TSA) Division of the Los Alamos National Laboratory (LANL). In accordance with guidance from the Department of Energy-Office of Fissile Material Disposition (DOE-MD), a separate report has been provided for each site under consideration for siting of a MOX FFF. A data call was prepared for the Department of Energy-Material Disposition Program (DOE-MD) by Science Applications International Corporation (SAIC) in early April of 1997, and an initial response was issued by the LANL MOX FFF team June 6, 1997. The June 6 release focused on providing SAIC the data required to begin work on the SPD EIS. The SPD EIS will evaluate the construction and operation of three plutonium disposition facilities, using the technologies decided upon in the Programmatic Environmental Impact Statement Record of Decision (PEIS ROD), at four candidate sites. The proposed plutonium disposition facilities are the Pit Disassembly and Conversion Facility (PDCF), the MOX FFF, and the Plutonium Conversion and Immobilization Facility (PCIF). The sites under consideration are the Hanford Site, the Idaho National Engineering and Environment and Engineering Laboratory (INEEL), the Pantex Plant, and the Savannah River Site (SRS). Not all sites are being considered for all facilities. The combinations of facilities and sites, i.e., the alternatives considered in the EIS, are delineated in the Notice of Intent (NOI) which appeared in the Federal Register on May 16, 1997.

Data for performing the SPD EIS analyses are being collected through a data call /data report process. The needed information is identified in information request packages (data calls) sent to cognizant entities responsible for supplying the requested information. Response documents are referred to as data reports.

Facility data calls were prepared to collect information relative to the construction and operation of a certain facility at a certain site. Thus, there is a facility data report that is specific to each proposed facility/location combination. The lead laboratory for each technology is responsible for preparing each of the facility data reports for the facilities using that specific technology.

Site Existing Environment data calls were also prepared for each of the four locations. The DOE Site National Environmental Policy Act (NEPA) Representative at each proposed location is responsible for preparation of the Site Existing Environment Data Report at that location. The Site Existing Environment Data Reports provide the site-specific baseline information from which to assess the potential impacts of the proposed actions.

The data and text presented in this MOX facility data report represent the best efforts of the MOX FFF EIS team to provide reliable input to the DOE and SAIC. Every effort has been made to ensure the completeness of the data as set forth in the Data Call of April 10, 1997. The detailed assumptions used in the development of the Initial Data Response are contained in Appendix A of this report. In general, it is assumed that the MOX FFF will be housed in a new building, constructed for that purpose, at each site. Separate reports or appendices will be issued addressing the possibility of housing the MOX FFF in an existing facility or co-locating it with either the pit disassembly or immobilization facilities.

The MOX facility is designed to fabricate plutonium-uranium mixed oxide fuel for light water reactors (LWRs) at a rate of 3.5 metric tons (MT) Pu metal/yr in order to dispose of 35 MT Pu metal over a nominal 10-yr period. Both boiling water reactor (BWR) and pressurized water reactor (PWR) fuel pellets, rods and assemblies may be manufactured, and additional space has been provided for the possible production of other fuel types (e.g. CANDU). The facility will be licensable by the Nuclear Regulatory Commission (NRC), and will comply with applicable federal, state and local environmental, health and safety requirements. The facility will receive uranium and plutonium oxide, which is in an unclassified form, for processing into MOX fuel. The entire facility will be available for inspection by the International Atomic Energy Agency (IAEA).

References are provided in the appropriate sections. In some cases, referenced data was not available and the values given are estimates based on best engineering judgment. References to recent European MOX experience have been used where available. However, much of the detailed information concerning operating European facilities is proprietary.

For analysis purposes, a generic preconceptual layout of a 114,000 ft^2 MOX FFF was used to provide a common basis for comparison of each candidate site. This generic layout was based on existing designs and MOX fuel fabrication experience and serves as a typical facility in which all the major functions appropriate to a MOX FFF are represented. A more detailed design of the actual MOX FFF will be conducted after DOE has selected the consortium of industry groups to design, construct, and operate the facility. Additional environmental analyses will be performed, as appropriate, to support the facility licensing process.

ACKNOWLEDGMENTS

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ACRONYMS AND ABBREVIATIONS

ACI	American Concrete Institute
AEC	Atomic Energy Commission
AF	Accident Frequency
ALARA	As Low As Reasonably Achievable
APSF	Actinide Packaging and Storage Facility
ASHRAE	American Society of Heating, Refrigeration, and Air Conditioning Engineers
ASTM	American Society for Testing and Materials
B&W	Babcock and Wilcox
BE	Best Estimate
BG	Below Grade
BM	Benchmark
BN	Belgonucleaire
BNFL	British Nuclear Fuels Limited
BSRI	Bechtel Savannah River, Inc.
BWR	Boiling Water Reactor
CANDU	Canadian heavy water reactors (Canadian Deuterium-Uranium)
CAS	Central Alarm Station
CCTV	Closed-Circuit Television
CEDE	Committed Effective Dose Equivalent
CFE	Critical Flood Elevation
CFM	Cubic feet per minute
CFR	Code of Federal Regulations
D&D	Decontamination and Decommissioning
DBA	Design Basis Accident
DBE	Design Basis Earthquake
DBW	Design Basis Wind
DOE	Department of Energy
DOT	Department of Transportation
DUO_2	Depleted Uranium Oxide
EDE	Effective Dose Equivalent
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
ERDA	Energy Research and Development Agency

ACRONYMS AND ABBREVIATIONS (CONT)

ERPG	Emergency Response Planning Guideline
FAA	Fuel Assembly Annex
FFTF	Fast Flux Test Facility
FMEF	Fuel and Materials Examination Facility
FPF	Fuel Processing Facility
FR	Fire Resistive
FSAR	Final Safety Analysis Report
HA	Hazards Analysis
HEPA	High-Efficiency Particulate Air
HEU	Highly Enriched Uranium
HLW	High-Level Waste
HVAC	Heating, Ventilating, and Air Conditioning
HWR	Heavy Water Reactor
IAEA	International Atomic Energy Agency
ICBO	International Code of Building Operations
ICPP	Idaho Chemical Processing Plant
IEEE	Institute of Electrical and Electronic Engineers
INEEL	Idaho National Engineering and Environmental Laboratory
LAA	Limited Access Area
LANL	Los Alamos National Laboratory
LEU	Low Enriched Uranium
LLMW	Low Level Mixed Waste
LLW	Low Level Waste
LWR	Light Water Reactor
MAA	Material Access Area
M&O	Management and Operating
MBA	Material Balance Area
MC&A	Material Control and Accountability
MD	Materials Disposition
MOX	Mixed Oxide
MO_2	Mixed Oxide
MT	Metric Ton
MTHM	Metric Tons Heavy Metal
NAA	Normal Access Area

ACRONYMS AND ABBREVIATIONS (CONT)

NDA	Nondestructive Analysis
NDT	Nondestructive Testing
NEC	National Electrical Code
NFPA	National Fire Protection Association
NM	Nuclear Material
NMSS	Nuclear Materials Safety and Safeguards
NPDES	National Pollutant Discharge Elimination System
NPH	Natural Phenomena Hazard
NRC	Nuclear Regulatory Commission
NSSFC	National Severe Storms Forecast Center
ORNL	Oak Ridge National Laboratory
ORR	Operational Readiness Review
OSHA	Office of Safety and Health Administration
PA	Protected Area
PAP	Personal Assurance Program
PCIF	Pit Conversion and Immobilization Facility
PDCF	Plutonium Disassembly and Conversion Facility
PEIS	Programmatic Environmental Impact Statement
PEL-TWA	Permissible Exposure Limit-Time Weighted Average
PFP	Plutonium Finishing Plant
PHMC	Project Hanford Management Contractor
PIDAS	Perimeter Intrusion Detection and Assessment System
PNNL	Pacific Northwest National Laboratory
PSA	Probabilistic Safety Assessment
PSAP	Personnel Security Assurance Program
Pu	Plutonium
PuO_2	Plutonium Oxide
PUREX	Plutonium - Uranium Extraction Plant
PWR	Pressurized Water Reactor
QA	Quality Assurance
RAA	Restricted Access Area
RCRA	Resource Conservation and Recovery Act
REACTS	Radiation Emergency Assistance Center/Training Site
REDOX	Reduction-Oxidation
RG	Regulatory Guide
ROD	Record of Decision

ACRONYMS AND ABBREVIATIONS (CONT)

ROM	Rough Order of Magnitude
RPSF	Radioisotope Power Systems Facility
S&S	Safeguards and Security
SA	Safety Analysis
SAF	Secure Automated Facility
SAIC	Science Applications International Corporation
SAR	Safety Analysis Report
SC	Safety Class
SCFM	Standard Cubic Feet per Minute
SNM	Special Nuclear Materials
SPD	Surplus Plutonium Disposition
SRP	Standard Review Plan
SRS	Savannah River Site
SRT	Special Response Team
SS	Stainless Steel
SSC	Structures, Systems, and Components
SST	Safe Secure Transport
STP	Standard Temperature and Pressure
SWEIS	Site-Wide Environmental Impact Statement
TI	Transport Index
TID	Tamper Indicating Device
TLV	Threshold limit value
TOC	Total Organic Carbon
TRU	Transuranic
UBC	Uniform Building Code
UCRL	University of California Radiation Laboratory
UHP	Ultra High Pressure
ULD	Unit Liter Dose
UO_2	Uranium Oxide
UPS	Uninterruptible Power Supply
VA	Vulnerability Assessment
WIPP	Waste Isolation Pilot Plan
WRPF	Waste Receiving and Packaging Facility

DEFINITIONS

The words and phrases used in this data report have the following definitions unless modified in a specific Section by a specific change to this definition:

Accident: An unplanned sequence of events that results in undesirable consequences.

Aqueous Process: An operation involving chemicals dissolved in water.

Batch: One lot of material that passes through the processing stages as a single unit of material.

Best Efforts: As used in this Data Call Report, best efforts describes the degree of skill and care provided in support of the preparation of this Data Call Report. It was rendered in a manner consistent with that ordinarily excised by members of the author's profession currently practicing under similar circumstances.

Blending: Mixing materials to achieve the desired composition and uniformity of material.

Criticality: A nuclear chain reaction (fission), initially increasing in magnitude, occurring in SNM which may or may not be sustainable, depending on the material properties at the time of criticality. A criticality accident may result in the release an intense burst of radiation and/or thermal energy. For MOX FFF criticality is defined as in accordance with the guidelines provided in the ANSI/ANS (American Nuclear Society) standards 8.3 and 8.15, "Criticality Accident Alarm Systems," and "Nuclear Criticality Control of Special Actinide Elements." Criticality events in fuel processing facilities are those accidents which result in a dose of 20 rads at a distance of 2 m in the first minute of the event.

Depletable Neutron Absorbers: Elements whose neutron-absorbing characteristics assist in nuclear reactor control. These can be fabricated directly into the fuel, coated on the fuel, or placed in the reactor coolant depending upon the specific reactor design.

Design Feature: A design feature is a characteristic of a piece of equipment or process configuration that fulfills a requirement. Examples of design features include one out of two logic, redundancy, and corrosion resistance.

Engineered Safeguard: A system or component, specifically designed to mitigate the consequences of a potential accident.

Engineering Judgment: As used in this Data Call Report, engineering judgment describes the methodology by which certain data values were determined. This methodology was used if actual referential values (data) were not available. In these cases, the values were determined based on expert consensus. In most cases, it represents a combination of subjective and collective expert opinion of the technical contributors to this Report.

Enrichment: Weight percent of plutonium (or U^{235}) as a fraction of total heavy metal.

Grinding: Applying abrasion to the outer surfaces of pellets to produce pellet sizes within the required specifications.

Hazard: The word "hazard" may be used in various contexts. In this Data Report an initiating event coupled with its potential consequences forms a hazard. A hazard may also be a source of danger (i.e. material, energy source, or operation) with the potential to cause illness, injury, or death to personnel or damage to an operation or to the environment (without regard for the likelihood or credibility of accident scenarios or consequence mitigation). [This definition from DOE Std. 3009-94].

Heavy Metal: Elements of atomic mass equal to or greater than uranium. In this document, this typically refers to a combined mass of plutonium and uranium.

Ion Exchange: Chemical process by which chemical compounds are altered to achieve desired forms.

Material Access Area (MAA): MAA means any location which contains special nuclear material, within a vault or a building, the roof, walls, and floor of which each constitute a physical barrier.

Metric Ton: 1000 kg.

Milling: Physical deformation of material to produce a specified particle size.

Mixed Oxide (MOX): MOX refers to a physical blend of UO_2 and PuO_2 fuels.

Oxide: The chemical compounds PuO_2 (plutonium oxide) or UO_2 (uranium oxide).

Pressing: Consolidation of the mixed-oxide powder to the desired pellet density and cohesion.

Procedures: Written and approved documents that delineate the methods by which an action is to be accomplished or controlled.

Record of Decision (ROD): A concise public document, issued no sooner than 30 days after completion of a final environmental impact statement or programmatic environmental impact statement, stating the agency's decision on the proposed action evaluated in the document. The ROD is not considered to be an environmental document since the decision may consider other factors in addition to environmental ones.

Scrap: Material left over from the fabrication process and recycled back into the system. In contrast, dirty scrap would be considered scrap which is contaminated, perhaps with some organic material, such that it can not be recycled but instead must be treated as waste (see waste herein).

Screening: Passing of material through a sieve to screen out particles of excessive size.

Sintering: Heating of the fuel pellets to join the oxide particles.

Special Nuclear Materials (SNM): As defined in the Atomic Energy Act, "'special nuclear materials' means (1) plutonium, uranium enriched in the isotope U^{235} or in the isotope U^{233}, and any other material which the Commission...determines to be special nuclear material, but does not include source materials."

Throughput: The rate of material processing in the facility.

Transuranic: Any element whose atomic number is higher than that of uranium. All transuranic elements are produced artificially and are radioactive.

Units: Engineering units used in this Data Report include both British and International Systems of Units (SI). Where British units are used, they are used because some of the original MOX conceptual designs were done using British units. The reported values are thus left in the most convenient form for use and comparison. Where appropriate, SI units are used. In most cases, where data is obtained from another source, the exact value is quoted. In the case of estimates or approximations, generally two significant digits are reported (e.g. 5.2E+2). In this case, the second digit is included to provide a relative order of magnitude (e.g. 9.0E+2 when divided by 2 would be reported as 4.5E+2 even though the 9.0E+2 value is an estimate).

Vault: Vault means a windowless enclosure with walls, floor, roof and door(s) designed and constructed to delay penetration from forced entry.

Vault-Type Room: means a room with one or more doors, all capable of being locked, protected by an intrusion alarm which creates an alarm upon the entry of a person anywhere into the room and upon exit from the room or upon movement of an individual within the room.

Vital Area: Vital area means any area which contains vital equipment.

Vital Equipment: Vital equipment means any equipment, system, device, or material, the failure, destruction, or release from which could directly or indirectly endanger the public health and safety by exposure to radiation. Equipment or systems which would be required to function to protect public health and safety following such failure, destruction, or release from are also considered to be vital.

Waste Types:

a) Hazardous Waste: Under the Resource Conservation and Recovery Act (RCRA), a solid waste, or combination of solid wastes, which because of its quantity, concentration, or physical, chemical or infectious characteristics may (a) cause or significantly contribute to an increase in mortality or an increase in serious, irreversible, or incapacitating reversible, illness, or (b) pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, disposed of, or otherwise managed. Hazardous wastes are defined in the RCRA regulations by appearance on lists or by exhibiting at least one of the following characteristics, also defined in the RCRA regulations: (1) ignitability, (2) corrosivity, (3) reactivity, or (4) toxicity. Source, special nuclear material, and by-product material, as defined by the Atomic Energy Act, are specifically excluded from the definition of solid waste. RCRA defines a "solid" waste to include solid, liquid, semisolid, or contained gaseous material.

b) Low-Level Waste: Waste that contains radioactivity and is not classified as high-level waste, transuranic waste, or spent nuclear fuel. Test specimens of fissionable material irradiated for research and development only, and not for production of power or plutonium, may be classified as low-level waste, provided the concentration of transuranic radionuclides (atomic number greater than 92) is less than 100 nCi/g of waste. Low-level waste is subject to the provisions of the Atomic Energy Act.

c) Low-Level Mixed Waste: Waste that contains both hazardous (as defined and regulated by the Resource Conservation and Recovery Act) and low-level radioactive components.

d) Transuranic Waste: Waste that is contaminated with alpha-emitting transuranic isotopes (atomic numbers greater than 92) with half-lives greater than 20 yr and concentrations greater that 100 nCi/g at the time of assay, except for high-level waste and other waste specifically excluded by DOE, EPA and/or NRC.

e) Mixed Transuranic Waste: Waste that is a combination of Low-Level Waste and/or Hazardous Waste and Transuranic Waste.

f) High-Level Waste: The highly radioactive waste material that results from the reprocessing of spent nuclear fuel, including liquid waste produced directly from reprocessing and any solid waste derived from the liquid that contains a combination of transuranic and fission product nuclides in quantities that require permanent isolation.

g) Nonhazardous Waste (Sanitary): Liquid wastes include sanitary sewage that is generally treated before discharge (stormwater is not included). Solid sanitary wastes include cafeteria and office wastes that are routinely generated by normal housekeeping activities, and can be disposed of in an ordinary sanitary waste landfill.

g) Nonhazardous Waste (Other): Other liquid wastes include nonradioactive and nonhazardous process wastewater, and cooling tower blowdown (stormwater is not included). These wastes may be treated in a process wastewater treatment system, or be treated by evaporation. Other solid wastes include construction and demolition debris such as, waste asphalt, concrete, lumber and metal, powerhouse ash, and treatment plant sludges. These solid wastes may be disposed of in a construction debris landfill, an industrial waste landfill, or a sanitary waste landfill.

Weapons-Grade: Plutonium with a Pu^{240} concentration less than 7%.

Weapons-Usable: A specific set of nuclear materials that may be utilized in making a nuclear explosive for a weapon. Weapons-usable fissile materials include uranium with U^{233} isotopic content of 20% or more, U^{235}, plutonium of any isotopic composition, and other special nuclear materials.

1. INTRODUCTION

This document is one of four that comprise revision 3 of the data reports which have been prepared in response to the Surplus Plutonium Disposition (SPD) Mixed Oxide (MOX) Fuel Fabrication Facility (FFF) Environmental Impact Statement (EIS) Data Call. These reports are being issued, in conjunction with the draft EIS, for public review and comment. The reports have been prepared by staff and contractors of the Technology and Safety Assessment (TSA) Division of the Los Alamos National Laboratory (LANL). In accordance with guidance from the Department of Energy-Office of Fissile Material Disposition (DOE-MD), a separate report has been provided for each site under consideration for siting of a MOX FFF. A data call was prepared for the Department of Energy-Material Disposition Program (DOE-MD) by Science Applications International Corporation (SAIC) in early April of 1997, and an initial response was issued by the LANL MOX FFF team June 6, 1997. The June 6 release focused on providing SAIC the data required to begin work on the Surplus Plutonium Disposition (SPD) Environmental Impact Statement (EIS). The SPD EIS will evaluate the construction and operation of three plutonium disposition facilities, at four candidate DOE sites, using the technologies decided upon in the Record of Decision for the Storage and Disposition of Weapons-Usable Fissile Materials Final Programmatic Environmental Impact Statement (PEIS ROD, Refs. 1 and 2). The proposed three plutonium disposition facilities are the Pit Disassembly and Conversion Facility, the MOX Fuel Fabrication Facility, and the Plutonium Conversion and Immobilization Facility. The four DOE sites under consideration are the Hanford Site, the Idaho National Engineering and Environmental and Engineering Laboratory (INEEL), the Pantex Plant, and the Savannah River Site (SRS). Not all sites are being considered for all facilities. The combinations of facilities and sites, i.e., the alternatives considered in the EIS, are delineated in the Notice of Intent (NOI) which appeared in the Federal Register on May 16, 1997.

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Site Existing Environment Data Calls were also prepared for each of the four locations. The DOE Site National Environmental Policy Act (NEPA) Representative at each proposed location is responsible for preparation of the Site Existing Environment Data report at that location. The Site Existing Environment Data Reports provide the site-specific baseline information from which to assess the potential impacts of the proposed actions.

The data and text presented in this MOX Technology data report represent the best efforts of the MOX FFF EIS team to provide reliable input to the DOE and SAIC. Every effort has been made to ensure the completeness of the data as set forth in the data call of April 10, 1997. The values specified in this report are being used to form, in part, the basis for SPD EIS. Further analysis performed in conjunction with the preparation of the SPD EIS may result in further refinement to these values. This draft report is subject to revision before the release of the final data report.

The detailed assumptions used in the development of the Initial Data Response are contained in Appendix A of this report. In general, it is assumed that the MOX FFF will be housed in a new building, constructed for that purpose, at each site. Separate reports or appendices may be issued addressing the possibility of housing the MOX FFF in an existing facility or co-locating it with either the pit disassembly or immobilization facilities. The facility is designed to fabricate plutonium-uranium mixed oxide fuel for light water reactors (LWRs) at a rate of 3.5 MT Pu metal/yr in order to dispose of 35 MT Pu metal over a nominal 10-yr period. Both boiling water reactor (BWR) and pressurized water reactor (PWR) fuel pellets, rods and assemblies may be manufactured, and additional space has been provided for the possible production of other fuel types (e.g. CANDU). The facility will be licensable by the Nuclear Regulatory Commission (NRC), and will comply with applicable federal, state, and local environmental, health, and safety requirements. The facility will receive uranium and plutonium oxides, which are in an unclassified form, for processing into MOX fuel. The entire facility will be available for inspection by the International Atomic Energy Agency (IAEA).

1.1. MOX Fuel Fabrication Facility Missions

The MOX FFF will accept surplus plutonium in oxide form and, through a well-established and practiced process, will fabricate mixed-plutonium oxide (PuO_2)-uranium oxide (UO_2) fuel. This fuel will be irradiated (burned) in the reactors selected for plutonium disposition. A number of types of water-cooled reactors are candidates for this mission.

The disposition of surplus weapons plutonium by incorporating it into MOX fuel and irradiating this fuel in reactors has been considered in a number of broad-ranging policy studies that deal with the disposition of excess fissile material. The most definitive of these is the National Academy of Sciences study on the Management and Disposition of Excess Weapons Plutonium (Ref. 1-3). The authors of this study regard the use of excess weapons plutonium for fuel in existing nuclear reactors as one of the two most promising alternatives for processing plutonium into a form that would make the plutonium as difficult to recover as the plutonium in existing commercial spent fuel.

The US Congress, Office of Technology Assessment (Ref. 1-4) and a RAND study (Ref. 1-5) also considered the use of plutonium in MOX fuel as an option for converting excess plutonium into a proliferation-resistant form. An American Nuclear Society (ANS) study (Ref. 1-6) recommended that the MOX fuel irradiation option be promptly implemented for the disposition of surplus plutonium. The technical viability of producing MOX fuel from excess plutonium was unquestioned in each of these studies because of European experience in producing MOX fuel from plutonium separated from commercial reactor spent fuel.

MOX fuel fabrication has been underway in Europe for some time. Additionally, several large state-of-the art facilities are nearing completion. A country-by-country review of European nuclear technology, including MOX fuel fabrication capabilities, is given in Ref. 1-7. Table 1-1 lists the MOX fuel plants that have been completed or are under construction. This table does not include several laboratory scale pilot plants that could produce small quantities of MOX fuel.

In France, the decision was made in 1985 to recycle plutonium in French PWRs. Experience with a 30% MOX assembly operation is described in Ref. 1-8. In the United Kingdom, early MOX experience was primarily with fast reactor fuel. Ref. 1-9 discusses the design of a MOX fuel plant for fast reactor fuel, the irradiation performance of the fuel, and the conversion of a pilot-scale plant to MOX production for thermal reactors. In Germany, the decision has also been made to recycle plutonium. Germany has significant pilot-scale experience with the manufacture of MOX fuel for LWRs. In addition, a large scale MOX facility was constructed (Ref. 1-10). Because of a changing political climate, there were difficulties in licensing the facility. The decision has been made not to proceed with licensing and operation of the facility.

MOX fuel fabrication technology and operational experience at the Dessel Plant in Belgium is described in Ref. 1-11. MOX fuel produced by this plant has operated without significant problems. The experience gained at the Dessel Plant has been used in the design of the next generation MELOX plant built in France. German experience in the use of MOX fuel is detailed in Ref. 1-12. Experience with this fuel has been satisfactory, with no MOX-specific characteristics that could limit the burnup potential of this fuel compared with UO_2 fuel. Experience in Belgium is discussed in Ref. 1-13. Performance has been good.

As part of the excess fissile material disposition decision making process, US and Canadian reactor vendors were contracted by the US Department of Energy to examine the feasibility of burning MOX fuel made from surplus plutonium in reactors of their manufacture. The results of these studies were used in the preparation of the specifications from which this report was developed. No significant technical barriers

TABLE 1-1.
WEST EUROPEAN MOX FUEL FABRICATION PLANTS

Facility	Operator	Capacity (MTHM/yr.)	Comments
Belgium			
Dessel P0	Belgonucleaire	35	Started up 1973.
France			
Cadarache	Cogema	30	Started up 1990.
Melox	Cogema	160	Completed 1995.
United Kingdom			
MDF	BNFL	8	Started up 1993.
SMP		120	To start up 1998.
Germany			
Hanau	Siemens	25 120	Facility completed, will not be operated because of opposition to licensing.

to the use of MOX fuel in existing or evolutionary reactors were noted in the vendor reports.

1.2. MOX Fuel Fabrication Facility Assumptions

The basis for the information in this data report is principally the past MOX research, development, and design efforts in the United States. In some cases, referenced data were not available, and the values given are estimates based on engineering judgment. In addition, much of the current MOX fuel fabrication activities in Europe are based upon research, development, and design efforts that took place in the United States during the 1960s and 1970s. References to recent European MOX experience have been used whenever available. However, much of the detailed information concerning operating European facilities is proprietary. More detailed design information will be available after DOE has selected the consortium of industry groups for the design, construction, and operation of the MOX FFF. Although the level of detail is not expected to have a significant effect on the results of the environmental analyses, additional environmental review will be performed as appropriate.

The MOX FFF accepts surplus plutonium in oxide form from storage. Uranium oxide is obtained in a form ready for processing. The basis for this report is UO_2 derived from depleted uranium; however, the use of natural uranium would be acceptable and may be used depending on actual production requirements. The PuO_2 is then combined with UO_2 and fabricated into MOX fuel for ultimate disposition in water-cooled, power-producing reactors. These reactors can be the heavy-water CANDU type or the light-water type, such as existing PWRs or BWRs. The general fabrication process is as follows: as required, oxide from off-site storage is received and entered into on-site storage, where it is appropriately cataloged. When needed for the actual fabrication process, the PuO_2 is retrieved from storage and prepared for MOX fabrication. The PuO_2 is blended with UO_2 obtained from an off-site supplier, fabricated into pellets, loaded into fuel rods, and assembled into fuel bundles. These bundles, which may be stored on site for up to 2 years, are then shipped to the disposition reactor site(s) for loading into the reactor.

Specific assumptions used to develop the preconceptual designs and data for the MOX FFF are listed in Appendix A of this report. Assumptions specific to a particular section of this report are quoted directly, as appropriate.

1.2.1. Facility Operating Basis. For the purposes presented here, the schedule for design, construction, operation, and decontamination and decommissioning (D&D) are summarized in Table 1-2. The primary constraint on this schedule is the coincident operation of the MOX FFF with that of the dispositioning reactor(s). A 3-yr construction period is assumed for a new facility based on engineering judgment and recent experiences in constructing nonreactor nuclear facilities. A 2-yr startup period, 1-yr for cold startup and 1-yr for hot startup is assumed. The operational phase start date has been fixed as 2006. The rest of the schedule has been extrapolated from that point. The nominal operating period of 10 yr is shown, along with a 3-yr D&D period.

1.2.2. Compliance. The facility will be designed, constructed, and operated in compliance with applicable existing federal, state, and local laws and regulations. In addition, the facility will be licensable by the NRC and inspectable by the IAEA.

1.2.3. Safeguards and Security (S&S). Safeguards and security must be implemented to ensure that nuclear materials and information are protected as required by DOE Orders, as well as applicable NRC regulations and IAEA requirements. In particular, special nuclear material (SNM) must be safeguarded according to the graded approach required by DOE Order 5633.3B and applicable NRC regulations. The graded approach provides for the most control for the types and quantities of SNM that can be used most effectively in a nuclear explosive device. The material in the MOX FFF will be highly attractive and protected. The SNM attractiveness levels and the quantities in the inventories for the facility will exceed the threshold for a Category I nuclear facility as defined in DOE Order 5633.3B. Thus, the facility's S&S systems must be designed to meet Category I protection requirements.

The S&S system must be designed to meet the Design Basis Threat, as well as any site-specific threats as evaluated by site-specific vulnerability assessments (VAs). It must protect against all possible malevolent acts, including theft of SNM, radiological and toxicological sabotage, and loss of classified and sensitive information. These threats from both outsiders and insiders include terrorists, criminals, disgruntled employees, and foreign agents. The targets for theft include plutonium and uranium oxides, fuel pellets, and pins/bundles in process or in storage.

TABLE 1-2.
FACILITY OPERATING BASIS

Activity	Yr.
MOX Team Selection/Contract Negotiation	1999
Design	2000 - 2001
Permitting/Licensing	2000-2006
Construction Phase	2002 - 2004
Cold Startup	2005
Hot Startup	2006
Operation Phase	2006 - 2015
Decontamination and Decommissioning and/or Conversion Phase	2015 - 2018 (nominal 3 years)

While providing the highest levels of protection and compliance with NRC regulations and IAEA requirements, as appropriate, the S&S system will:

1. minimize impact on operations;
2. complement other areas of facility operations (including nuclear safety, process control, quality control, and radiation protection);
3. be integral to facility design and minimize S&S costs; and
4. maximize reliability by using proven state-of-the-art technology.

Physical protection, material control, and accountability are important considerations in planning and designing the facility. In addition, classification, clearances and personnel security programs will be required and implemented according to current NRC regulations and guidance.

1.2.4. Environment, Safety, and Health. The new MOX FFF design will comply with applicable federal, state, and local laws and regulations. Additional industry consensus codes and standards will be applied to the design as appropriate.

The facility structures, systems, and components will be designed, fabricated, erected and tested in accordance with 10CFR50, Appendix B, or ASME/ANSI NQA-1 requirements. These standards are commensurate with the risks associated with a given facility and the significance of each structure, system, and component in mitigating releases of radioactive and other hazardous materials or minimizing risks.

As low as reasonably achievable (ALARA) radiological exposure principles will be incorporated throughout the design and operation of the facilities.

Because of the unique nature of this facility, the waste quantities stated in this document represent estimates based on a combination of the operating history at the Los Alamos National Laboratory Plutonium Facility, and known processing data from other sites and previously designed MOX FFFs. Estimates are conservative in order to provide an upper bound while maintaining a high degree of confidence.

Environmental data (effluents and resource requirements) presented in this report are based on data from similar facilities within the existing weapons complex and the nuclear power industry. Adjustments have been made where appropriate.

Nuclear criticality safety controls (achieved through a composite of design and administrative measures) will ensure that operations involving plutonium are conducted so that an adequate margin of subcriticality exists during all normal and abnormal conditions. Where feasible, inherently safe geometries will be employed.

All fire sprinkler water discharged in process areas is contained and treated as process wastewater.

The facility will include a storm water collection system with the requisite National Pollutant Discharge Elimination System (NPDES) Storm Water Permit and applicable monitoring equipment. Rainfall within the Facility Limited Area and Protected Area will be collected and routed through the storm water collection system in accordance with the terms and conditions of the NPDES Storm Water Permit. The MOX FFF storm water permitting will be consistent with existing DOE SRS site NPDES permits and state of South Carolina and Environmental Protection Agency (EPA) requirements, and will be addressed as part of the actual MOX FFF design process

Airborne emission estimates are based on the use of coal as the primary fuel to the boilers and other miscellaneous energy users.

A regional Radiation Emergency Assistance Center/Training Site (REACTS) facility is assumed to be available; monitoring and decontamination facilities, such as stabilization, mild decontamination, and staging for REACTS, are included on site.

The facility design is designed so that operators are not required to wear respiratory protection to meet radiological exposure limits while conducting routine operations. An exception is that respirators will be routinely required for downdraft operation. It is anticipated that the facility design will use a high degree of automation/robotics where practical, to reduce personnel exposure and for SNM accountability (Ref.1-21).

1.2.4.1. Buffer Zones. The proposed location for the MOX FFF at SRS is in an existing DOE facility. As such, a buffer zone is provided between the plant operations boundary and the site boundary. Distances between the buildings are based on technical, safety, and security considerations.

1.2.4.2. Decontamination and Decommissioning. The facility design considers and incorporates provisions for D&D.

1.2.4.3. Nonsafety/Safety Class. The safety classification of structures, systems and components, including instrumentation and controls, will be derived from the safety functions performed. This safety classification is based on NRC requirements (Regulatory Guides 1.29 and 1.26).

Safety class instrumentation will be designed to monitor identified safety-related variables in safety class systems and equipment over expected ranges for normal operation, accident conditions, and safe shutdown. When required, safety class controls will be provided to control these variables.

Suitable redundancy and diversity will be used when designing safety class instrumentation to ensure that safety functions can be completed when required, and that a single-point failure will not cause a loss of protective functions. Redundant safety class signals also must be protected physically or separated to prevent a common event from causing a complete failure of the redundant signals. Regulatory Guide 1.75, IEEE Standards 379 and 384 are the design basis for redundancy and separation criteria. Safety class instrumentation will be designed to fail in a safe mode following a component or channel failure. Safety class uninterruptible power supply (UPS) power will be provided when appropriate.

1.2.4.4. Toxicological/Radiological Exposure. The facility will be designed so that during normal operations worker exposure to toxic agents will be below regulatory limits. The ALARA process will be implemented in the design as it affects worker exposure to toxic agents and radiation exposure.

Worker exposure to radiation will not exceed the annual dose allowance under NRC requirements (5.0 rem effective dose equivalent [EDE]). The goal for facility workers is a maximum exposure of 0.5 rem EDE/yr. The dose in any unrestricted area will not exceed 2 mrem/hr. Public exposure to radiation at the site boundary from normal operations will not exceed 100 mrem/yr and for any accident will not exceed 5 rem EDE/yr according to 10CFR20.1301. The goal for the facility for public radiation exposure will be to operate the facility so that public exposure, if any, will be below this statutory value. The facility will be designed to minimize and control the number of people required to work in contaminated or toxic areas.

1.2.4.5. Waste Management. Generation of all wastes is minimized subject to the constraints of ALARA.

No high level waste (HLW) will be generated.

Low level waste (LLW) is disposed of off site.

Transuranic (TRU) waste is stored on an interim basis and then shipped to the Waste Isolation Pilot Plant (WIPP), where applicable.

Hazardous waste is shipped off site to an authorized Resource Conservation and Recovery Act (RCRA) facility for treatment and/or disposal.

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2. NEW MOX FUEL FABRICATION FACILITY DESCRIPTION

This section provides a general description of the MOX FFF, gives an overview of safety considerations, and addresses issues relevant to the protection of SNM in a MOX fuel fabrication process. The detailed site-specific facility description is presented in section 3. A detailed safety and accident analysis is provided in section 8.

2.1. General Facility Description

Plutonium oxide will be incorporated into MOX fuel assemblies for use in a power-producing reactor. The facility contains all of the buildings and infrastructure required to house unit operations, waste management, maintenance, utilities, general and administrative activities, and safeguards and security.

2.1.1. Facility Functional Description. The purpose of the facility is to take PuO_2 from a storage facility(s), combine it with UO_2 supplied by a commercial vendor, and produce mixed PuO_2-UO_2 that is suitable for reactor fuel, and to assemble fuel bundles with this MOX fuel for use in a power-producing reactor. The fuel bundles may use only MOX fuel pins, or they may incorporate both MOX fuel and enriched UO_2 fuel pins, depending on the reactor type and on reactor neutronics (fuel burnup) requirements. It is anticipated that fully assembled enriched UO_2 fuel pins would be shipped to the MOX FFF for incorporation into the fuel bundles. All operations will be carried out in an environmentally safe manner. Figure 2-1 depicts the flow of key materials within the MOX FFF.

2.1.2. Plot Plan. The fuel fabrication building will be a new structure, as depicted in section 3 of this data report.

2.1.3. Building Descriptions. The following descriptions relate to the overall MOX mission facility requirements.

2.1.3.1. Fuel Fabrication Building. The fuel fabrication building is the central structure for the MOX mission. It houses most of the critical features. Table 2-1 shows an estimate for the total footprint area required for the processes located within the building. This building will be hardened to protect if from external natural hazards and access to the facility will be restricted in accordance with NRC safeguards and security requirements.

2.1.3.2. Waste Management Facilities. The waste management facilities will process, temporarily store, and ship all wastes generated by the MOX FFF. This will include all solid, liquid, contaminated, or uncontaminated wastes. The waste processes and handling areas will be segregated by waste form. All wastes will be controlled and accountability will be provided.

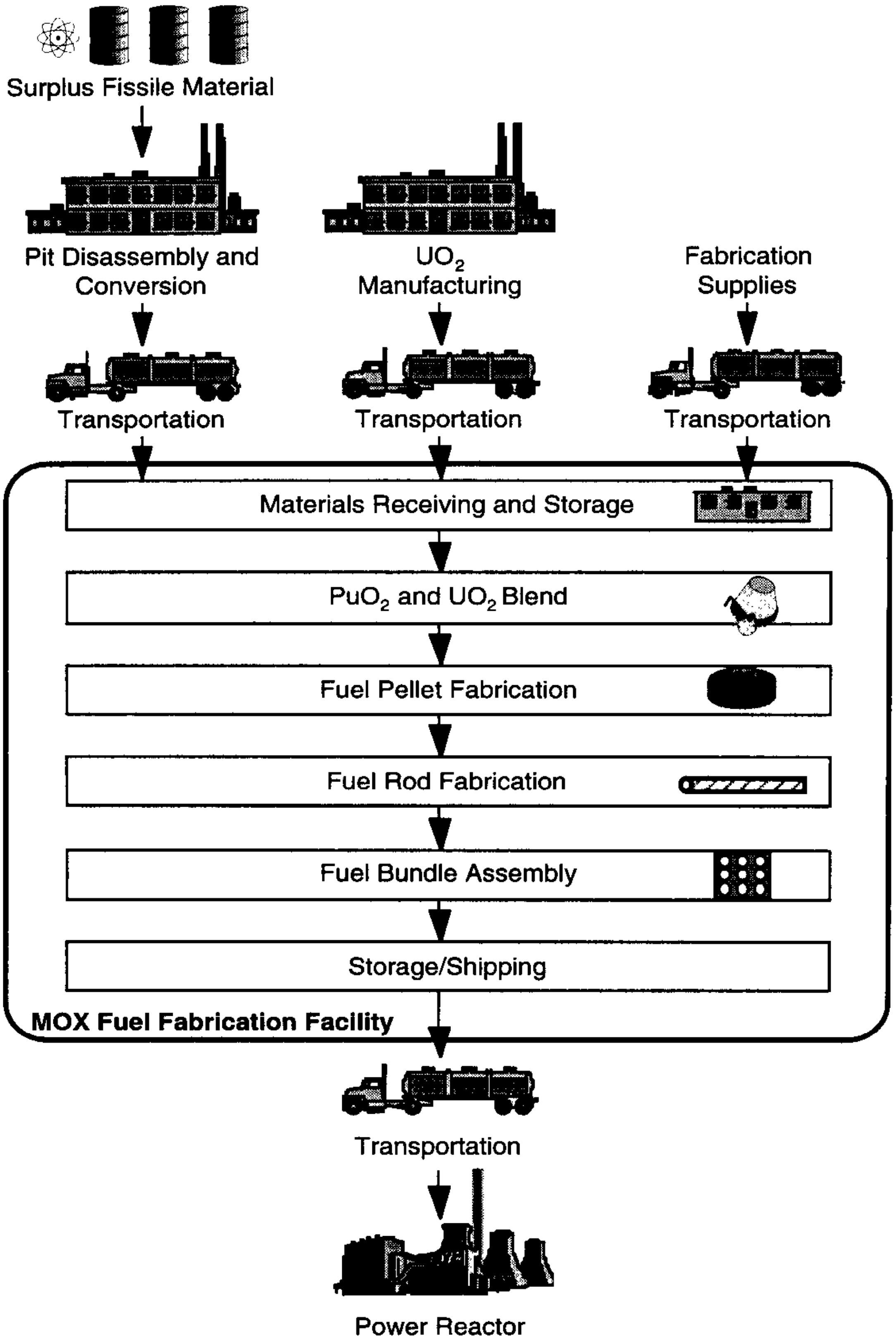

Fig. 2-1. Material flow diagram.

Table 2-1. MOX Mission Building Data

MOX Mission Function	Est. Area ft^2 { } = total area	Levels (floors)	Special Materials	Construction Type
Materials receiving and storage warehouse	20,000	1	None	Metal Building
MOX FFF Building	70,000 1st flr 44,000 bsmt {114,000}	2	SNM	Type-1 FR, SC-1[a]
Fuel fabrication portion of the MOX FFF	~30,000 1st flr ~15,000 bsmt {~45,000}	2	SNM	Type-1 FR, SC-1[a]
Waste management portion of the MOX FFF	~10,000 1st flr ~15,000 bsmt {~25,000}	1	SNM	Type-1 FR, SC-1[a]
Cold support and utilities portion of the MOX FFF	~15,000 1st flr ~14,000 bsmt {~29,000}	2	None	Type-1 FR
General administration and support office	~10,000 1st flr ~10,000 2nd flr {~20,000}	2	None	Type-1 FR
Security building/access control	~5,000	1	None	Type-1 FR, SC-1[a]
Fire Station	~5000	1	None	Type-1 FR

This table is partially generic, applicable to all candidate sites.

[a]Type-1 Fire Resistive, reinforced concrete, Safety Class-1 according to the Uniform Building Code.

~ This area represents a portion of the MOX FFF and is an approximation only.

2.1.3.3. Chemical Storage Area. The chemical storage area will provide space for chemical storage tanks that supply the buildings and processes in the Protected Area (PA). This building is considered to be a PA.

2.1.3.4. General Administration and Support Building. The general administration and support building provides office and support space for the site. This would be a new building and would be located adjacent to F Area as shown in section 3.

2.1.3.5. Security/Access Control Building. The security/access control building provides office and support space for the site security personnel as well as the MOX FFF access control point. This building would be located adjacent to the new MOX FFF in F Area and would be an integral part of the MOX FFF perimeter control fence, thereby allowing for both administrative and access control functions.

2.1.3.6. Fire Station. The fire station provides support to the site for immediate response to fire and medical emergencies. At SRS, this building is located in the F Area, which should provide adequate response time; therefore, an additional fire station is not needed.

2.1.3.7. Utilities Area. The utilities area is the entrance and metering point for electrical, natural gas, and water supplies. The electrical substation, emergency generator(s), and associated switching equipment are located in this area. This building is located within the facility area.

2.2. Design Safety

The following sections identify some important safety considerations to be incorporated in the design of the facility. Performance goals commensurate with the associated hazard will be selected for all structures, systems, and components (SSCs). The term "hazard" is defined as a source of danger, whether external or internal. Natural phenomena such as earthquakes, extreme winds, tornadoes, and floods are external hazards to the SSCs, whereas toxic, reactive, explosive, or radioactive materials contained within the facilities are internal hazards.

2.2.1. Earthquake. All new plant SSCs will be designed for earthquake generated ground accelerations in accordance with NRC Regulatory Guide 3.14, "Seismic Design Classification for Plutonium Processing and Fuel Fabrication Plants."

Seismic design considerations for Seismic Category I and II SSCs (see NRC Regulatory Guide 1.29) will include provisions for such SSCs to function as hazardous materials confinement barriers and also for adequate anchorage of building contents to prevent their loss of critical function during an earthquake. In essence, design considerations avoid premature, unexpected loss of function and maintain ductile behavior during earthquakes.

Characteristics of the lateral force design are as important as the magnitude of the earthquake load used for design. These characteristics include redundancy, ductility, and specified materials and construction. Other factors that need to be considered include the behavior of combined elements once they are made into a unit; the behavior of non-uniform, non-symmetrical structures or equipment; the detailing of connections and reinforced concrete elements; and whether equipment is adequately anchored.

In addition to structural safety, the operation of emergency systems during and after an earthquake is essential. The fire protection system, emergency power, water supplies, and controls for safety class equipment are examples of plant systems that may be required to be available following an earthquake.

2.2.2. Wind. All new plant SSCs will be designed for wind or tornado load criteria at specific DOE sites in accordance with NRC requirements.

Wind design criteria will be based on the annual probability of exceedance, importance factor, missile criteria, and atmospheric pressure change, as applicable to each performance (usage) category as specified in Table 5-2 of UCRL-15910.

2.2.3. Flood. All facilities and buildings should preferably be located above the critical flood elevation (CFE) from any potential flood source (river, dam, levee, precipitation, etc.), or the site/facility will be hardened to mitigate the effects of the flood source so that performance goals are satisfied. Emergency operation plans will be developed to safely evacuate employees and secure areas with hazardous, mission-dependent, or valuable materials. The facility will be designed to meet NRC design basis flood criteria (see Refs. 1-12, 2-4, and 2-5)

Site drainage must comply with the regulations of the local governing agency. The minimum design level for the storm water management system is the 25-yr, 6-h storm, but potential effects of larger storms up to the 100-yr, 6-h storm will also be considered. However, storm water management systems must prevent the CFE from being exceeded. Accordingly, for some facilities, storm water management systems may have to be designed for more extreme storms.

2.2.4. Fire Protection. The fire protection features for the plant and its associated support buildings will be in accordance with the NRC Regulatory Guide 3.16, "General Fire Protection Guide for Plutonium Processing and Fuel Fabrication Plants (Ref. 2-6)," and the National Fire Protection Association Fire Codes and Standards (Ref. 2-7).

Redundant fire water supplies and pumping capabilities (electric motor drivers with diesel backup) will be installed to supply the automatic and manual fire protection systems located throughout the site. The facility may be tied into the existing high pressure fire loop. One supply and one set of pumps will be designed to meet design basis event requirements. Appropriate types of fire protection systems will be installed to provide life safety, prevent large-loss fires, prevent production delay, ensure that fire does not cause an unacceptable on-site or off-site release of hazardous material that will threaten the public health and safety or the environment, and minimize the potential for the occurrence of a fire and related perils.

Specific production areas and/or equipment will be provided with the appropriate fire detection and suppression features as required with respect to the unique hazard characteristics of the product or process.

A fire hazards analysis will be performed in accordance with NRC requirements to assess the risk from a fire within the individual fire areas of the facility.

All fire sprinkler water that has been discharged in process areas during and after a fire will be contained, monitored, sampled, treated in the process wastewater treatment plant, and disposed of.

2.2.5. Safety Class Instrumentation and Control. The safety classification of the instrumentation and controls will be derived from the safety functions performed. This safety classification is based on NRC Regulatory Guides 1.26 and 1.29 (Refs. 2-8 and 2-2).

Safety class instrumentation will be designed to monitor identified safety related variables in safety class systems and equipment over expected ranges for normal operation, accident conditions, and for safe shutdown. Safety class controls will be provided, when required, to control these variables.

Suitable redundancy and diversity will be used when designing safety class systems to ensure that safety functions can be completed when required and that a single point failure will not cause loss of protective functions. Redundant safety class signals must also be physically protected or separated to prevent a common event from causing a complete failure of the redundant signals. Regulatory Guide 1.75, Standards IEEE 379 and IEEE 384 (Ref. 2-9) are the design basis for redundancy and separation criteria. Safety class instrumentation will be designed to fail in a safe mode following a component or channel failure. Safety class uninterruptible power will be provided when appropriate.

2.2.6. Nuclear Criticality. Where the potential for nuclear criticality exists, the design of the plant will include the basic controls for ensuring nuclear criticality safety. Designs will satisfy the double contingency principle, i.e., "process designs will incorporate sufficient safety factors so that at least two unlikely, independent, and concurrent changes in process conditions must occur before a criticality accident is possible," (see NRC Regulatory Guide 3.34, 3.47, 3.57 and ANSI/ANS 8.12 [Refs. 2-10 through 2-13]). Basic control methods for the prevention of nuclear criticality include

1. provision of safe geometry (preferred),
2. engineered density and/or mass limitation,
3. provision of fixed neutron absorbers,
4. provision of soluble neutron absorbers, and
5. use of administrative controls.

Although geometric controls are used extensively wherever practical, there are cases in which geometric control alone cannot practically provide assurance of criticality safety. In these cases, engineered controls can be used to control moderation, nuclear poisons, mass, and density. The NRC nuclear criticality regulations and requirements will be applied to the design of the facility to prevent criticality excursions.

2.2.7. Ventilation. The HVAC system design for the new facility will meet all general design requirements in accordance with NRC Regulatory Guide 3.12, "General Design Guide for Ventilation Systems of Plutonium Processing and Fuel Fabrication Plants (Ref. 2-14)," and the ASHRAE guidelines (Ref. 2-15).

The HVAC system provides environmental conditions for the health and comfort of personnel and for equipment protection. Typically, the ventilation system will be designed to maintain confinement to preclude the spread of airborne radioactive particulates or hazardous chemicals within the facilities and to the outside environment.

The design includes engineered safety features to prevent or mitigate the potential consequences of postulated design basis events. Suitable redundancy and diversity will be used when designing the ventilation system to ensure that the mitigation of design-basis events can be completed, when required, and that a single point failure will not cause loss of protective functions. Multiple barriers are used to limit the release of plutonium from the facility manufacturing building. These include both a series of structural barriers to form zones or areas and zoned ventilation systems. Primary confinement is provided in Restricted Access Areas (RAAs) by process enclosures such as shielded gloveboxes or hot cells, where the plutonium handling equipment is located. Outside the RAA there may be an area used for operation and maintenance, designated as a Limited Access Area (LAA), which serves to contain any leakage of contamination from the RAA. The limited access barrier forms a fire and shielding wall. The final confinement is provided by the building walls, which enclose the Normal Access Areas (NAAs).

Pressure differentials are maintained between areas so that air flows from non-contaminated areas into areas of potentially higher contamination levels, where RAA pressure < LAA pressure < NAA pressure < atmospheric pressure. Differentials are maintained by automatically controlled zone ventilation systems that are equipped with redundant, independent emergency power supplies.

Gas in the gloveboxes and in the glovebox gas supply and exhaust gas system make up Zone 1. Air in the process rooms external to the gloveboxes is monitored continuously for airborne contamination. Gas at the exit of Zone 1 filtration is also monitored continuously for contamination, and a high level of radioactivity in the Zone 1 exhaust is cause for Zone 1 shutdown and facility evacuation. Loss of Zone 1 flow or negative pressure is cause for immediate facility shutdown.

The model facility exhausts process air through a minimum of three high-efficiency particulate air (HEPA) filters, with the first HEPA filter usually located on the glovebox. The two final stages have an in-place test capability.

2.2.8. Confinement and Containment. Confinement and containment of nuclear material will be provided for the FFF by the building structure and the ventilation system. This confinement system includes the entire external structure and the ventilation system.

The FFF will be designed and constructed to withstand the forces of a Design-Basis Earthquake (DBE) and all postulated facility accidents without building failure or significant cracking. Because of this design approach, confinement can be considered to be provided by the seismically qualified building and ventilation systems that isolate the building from the environment in emergency situations. Primary confinement is provided by the glovebox system and the associated zone air handling system. Operations involving nuclear material are carried out within the gloveboxes in the building.

All gloveboxes will l
Standard connectors
minimizing contami
to shield operating p

The interior of the g
and all welds will l
window, glove port
seals to a level that is
of stainless steel, an
structure of the boxes

effective, more economical, and less intrusive. Because of increased concerns about nuclear proliferation, public awareness, and the uniqueness of these plutonium processing facilities, S&S systems will be required to meet the highest standards of performance and compliance.

The MOX FFF accepts surplus fissile material in oxide form and produces MOX fuel for commercial power reactors. The SNM quantities in inventories and the attractiveness levels for the facility will exceed the threshold for a Category I nuclear facility as defined in DOE Order 5633.3B (Ref. 2-17). Thus, the fabrication facility S&S systems must be designed to meet Category I protection requirements.

2.3.2. Physical Protection. Physical protection of facilities includes protection in depth (several layers of protective measures providing detection, delay, and response), balanced protection (nearly equal detection and delay on all possible adversary paths to similar targets), graded protection (response commensurate with the asset being protected), and reliability (minimal susceptibility to single point failures and low maintenance requirements). The physical protection system will use proven S&S systems and components that have been validated at other facilities or test programs and that still allow for future technology advances. Technology will minimize the cost of protective force personnel. The protection system and facility operations will provide compartmentalization of the facility to minimize personnel access to potential targets of malevolent acts. Compartmentalization will also be applied to minimize areas where classified information can be derived.

Protection planning will be based on relevant DOE/NRC/IAEA requirements and a site-specific VA. The VA will identify the appropriate levels of protection for each potential type of material against each potential type of adversary and threat (e.g., theft or sabotage, as defined in the design basis threat guidance). Material will be protected while in storage, in process, and in transit.

2.3.2.1. Personnel Security Measures. Personnel security measures will include the appropriate access authorizations for employees. Personnel meeting established security criteria will also be required to enroll in human reliability programs [e.g., the Personnel Assurance Program (PAP) and the Personnel Security Assurance Program (PSAP)].

2.3.2.2. Barriers and Access Control Systems. An important part of the physical protection system of the facility will be barriers that impede, delay, or, in some cases, deny access to nuclear material. Delay levels will be determined by barrier technology data and/or the performance of a vulnerability assessment. Barriers will consist of concentric layers of graded protection and defense-in-depth measures. Types of passive barriers include fencing, hardened walls, vault doors, locking systems, and geologic formations. Active barriers may include dispersed foam and smoke.

Clearly defined physical barriers such as fences, walls, and doors will be used to control, impede, or deny access to the PA. The PA perimeter, which will contain the fabrication facility, will be defined by security fences and automated intrusion detection systems similar to or equivalent to a DOE facility security system (Perimeter Intrusion Detection and Assessment System [PIDAS]).

All pedestrian and vehicular traffic will be controlled through an entry post. The entry post will be designed for inspection and search of personnel, hand carried items, and vehicles. Each personnel entry portal will have badge readers, a portal metal detector (for entry), nuclear material portal detectors (for exit), a package x-ray system, and space for security inspectors to perform hand searches of packages suspected of containing prohibited articles. The vehicle portal will be equipped with vehicle traps and SNM monitors.

The terrain surrounding the facility perimeter will be modified to prevent vehicles from ramming into it. At those areas where vehicles can access the PA perimeter, barriers will be installed to preclude ramming. Guidance on these types of installations will be taken from the Sandia National Laboratories' *Barrier Technology Handbook* (Ref. 2-18).

Category I quantities of SNM in storage or in process must be contained within a Material Access Area (MAA), which is within a PA. Category I SNM must be stored in vaults or vault-type rooms that meet the NRC requirements.

The receiving and storage, fuel fabrication, and waste management buildings will be contained within a (MAA). This MAA will be contained within the facility PA, and the exterior walls will be constructed to the specifications of an SNM vault. All personnel entering the MAA will be channeled though an entry post, under security police officer control. The entry post will contain portal metal detectors and portal SNM monitors. Vehicular traffic will not be permitted to enter the MAA.

2.3.2.3. Detection and Alarm Systems. A detection system will be installed (using up-to-date technology) at all PA/MAA boundaries, vital areas, vaults, and vault-like rooms to signal attempted intrusion, unauthorized attempt at access, or other anomalous situations. This detection system will include access control facilities at each portal, where the identity of each employee is verified. A computerized entry control system will maintain a real-time record of all persons present in the PA and MAA (see section 2.3.2.1). Any alarm anomaly will be displayed on a console in the central alarm station (CAS). Security personnel will direct an appropriate response.

The following criteria will be applied to the selection and deployment of alarm systems: (1) required probability of detection and false alarm rates, (2) circuitry to detect tampering with sensors, wiring, or other system components, (3) backup electrical power when site power is lost, (4) wiring and system component placement to be contained inside the PA, (5) use of suitable conduit and tamper-protected enclosures for alarm wiring, and (6) ability to test detection sensors.

All electronic detection systems will meet site-specific protection needs and the following requirements: (1) all detection/alarm devices will be connected to monitor or display panels in the central alarm station; (2) exterior sensors that serve as the primary means of detection at the PA perimeter will provide reasonable assurance in detecting penetration of the perimeter; (3) the system, including transmission lines, will be failure and tamper indicating in both the access and secure modes; (4) the system transmission lines will be continuously supervised; and (5) the system will have a primary and auxiliary power source.

2.3.2.4. Assessment Systems. Upon receipt of an alarm or detection of an intrusion, the nature of the threat will be evaluated and an appropriate response initiated. In general, the special rapid-response team will be activated. Further assessment of the alarm may be accomplished before the arrival of the rapid-response team.

2.3.2.5. Communication Systems. All security police officers will be equipped with transceivers equipped with digital encryption systems for two-way communications. The Central Alarm Station (CAS) will be substantially constructed to provide the required protection to personnel and communications equipment. The communications equipment is tested on a continual basis through regular use and through hourly communication checks. All security police officers at fixed positions will have normal telephone services and two-way communications with other fixed stations. In the case of catastrophic power failure (normal and backup), the central guard station will have communications with local police departments.

2.3.2.6. Response Systems. The primary and first response to an overt intrusion or attempt at theft or sabotage of nuclear material will be by facility security police officers. If the MAA is the source of the alarm, the special rapid response team will assist on-site officers. All security posts will be equipped with duress alarms and located in accordance with the latest DOE orders or NRC requirements.

2.3.2.7. Lighting Systems. The perimeter lighting will comply with the latest DOE orders (5632.7 series ([Ref. 2-19]) or NRC requirements and will be compatible with both visual observation by security police officers and an event-actuated closed circuit television system (CCTV). The perimeter lighting will be powered by commercial power with backup power from a backup generator.

2.3.2.8. Protective Force. Protective force staffing levels and operational capabilities will be sufficient to neutralize the postulated adversary threats. Detection levels will be determined by intrusion detection performance data and/or by conducting a vulnerability assessment performance test. These personnel will be subject to appropriate human reliability programs (e.g., PAP and PSAP).

2.3.3. Nuclear Material Control and Accountability. The nuclear MC&A system for the MOX FFF will be a single integrated system of accountability measurements and material control measures to monitor storage, processing, and transfers. The system will be a computerized database management system employing double-entry accounting. The system will have the capability for recording external receipts and shipments and internal transfers between and within material balance areas (MBAs). The record system will categorize nuclear material by material type, composition, and location. The system must be capable of tracking nuclear material throughout the facility, including each of the processes used to perform fabrication activities. The system must be capable of locating items by specific storage locations for material in storage.

As appropriate, the MC&A system will be designed and implemented to be closely associated with process control, access control, and criticality safety. Material control measures will govern all movement, processing, and access to SNM. Backup systems will be incorporated so that a single failure will not compromise this monitoring and detection capability. The accounting system will provide timely information for the location and quantities of all nuclear material in the facility at any time and will be designed to detect abrupt or protracted thefts or diversions. The system will provide a means of physically accounting for the disposition of nuclear material.

2.3.3.1. Nuclear Material Control Systems. The facility will have an MC&A custodian whose responsibilities will include evaluating MC&A anomalies. The material control systems that will be evaluated by the MC&A custodian include measurement control charts, daily checks on the nuclear material (daily administrative checks), and material in-process reports. Personnel who detect or suspect missing nuclear material or unauthorized activities are required to report the situation immediately.

The outer boundary of the MAA is defined as the perimeter walls of the buildings containing the operations with SNM. The MAA will be apportioned into material balance areas predicated on operating procedures, physical configuration of laboratories or processing equipment, and assay capabilities. The MBA structure is designed to optimize control of nuclear materials.

The objective of the MAA boundary is to prevent or detect the unauthorized movement of material though it, while allowing access for authorized personnel, authorized material movement, and emergency evacuation, as necessary. Nuclear material will be transferred into and out of the MAA at well-defined locations and will be subject to specific procedures that prevent unauthorized transfers.

The MAA boundary will be designed to incorporate emergency exits in compliance with the National Fire Protection Association Life Safety Code (NFPA 101) (Ref. 2-20).

Material awaiting processing will be stored in a graded system with appropriate access controls. The facility will have a vault for nuclear material awaiting processing. Vault activities will be subject to strict material surveillance procedures. All personnel movement into and out of the vault will be controlled by access procedures. During non working hours, the vault will be secured and alarmed.

Process equipment, such as glovebox lines, often provides a natural barrier to the theft and diversion of nuclear material. This equipment will be used to supplement other safeguards and security measures.

The two-person rule and/or electronic surveillance systems such as CCTV will be implemented when required for use in sensitive areas such as loadout stations, transfer locations, and outside doors.

A tamper-indicating device program will be documented and implemented. The design of MAA doors, vault doors, vault racks, and material containers will include seal mechanisms.

2.3.3.2. Material Accountability Program. The facility accountability program will include an accounting system, a measurement and measurement control program, physical inventory programs, a material transfer program, and a program to assess material control indicators.

The accounting system will be a near real-time accounting system. This system will require the prompt reporting of any change to the nuclear material accountable quantity, location, user, and form. The nuclear material inventory will be maintained on a computerized database. Configuration of the database will allow users, custodians, and oversight groups to efficiently and accurately assess the status of all accountable nuclear material items in the MAA.

The MC&A computer system will be located in a security area within the PA and will be operated under physical and administrative controls described in an approved automatic data processing security plan. Access to the computer system must be restricted through physical, administrative, and password controls. Control over software must be provided through physical software protection and a change control system.

MC&A data is protected at the highest classification level for data in the system. Access to MC&A data is also limited on a need-to-know basis. MC&A data stored on the computer system must be backed up daily to supplementary disk files that are stored in a separate location. Data and reports are retained in accordance with DOE directives and requirements.

Space and equipment will be provided for performing accountability measurements. Quantities of SNM on inventory and involved in external/internal transfers are verified and/or confirmed through standardized measurement, sampling, and analytical techniques. The same techniques are used in the performance of plant physical inventories. Various measurement methods are employed, depending upon the type and form of the material and the purpose of the measurement. Measurements performed for accountability in the fabrication facility may include mass, nondestructive analysis (NDA), and destructive (chemical) analysis.

The MC&A system will ensure that the quantities of nuclear material are stated with the timeliness, accuracy, and precision requirements of the NRC requirements. The measurement subsystem will include the statistical evaluation of all measurement data to determine instrument control limits, calibration limits, and the precision and accuracy levels for each measurement system.

Physical inventories are required at specified intervals to verify the accuracy of the SNM records for each MBA. An exception to this is in storage areas where the additional S&S measures provide assurance of the continuing presence and integrity of the material. Inventory intervals as long as 3 yr are possible provided certain criteria can be met. It has not been determined whether the storage areas in the fabrication facility can be designed to qualify for extended inventory intervals. The process area will have to meet the bimonthly interval requirement.

External receipts at the fabrication facility will consist of surplus fissile material in oxide form. Shipments from the facility will be MOX fuel bundles. Tamper-indicating devices are applied to all containers before shipment. The capability for verification measurements of receipts and shipments must be provided.

Internal transfers of SNM are controlled in accordance with NRC requirements (10CFR74). Transfers of SNM between MBAs may require a confirmation or verification measurement depending upon the quantity, measurement history, and whether or not tamper-indicating devices have been applied to the transferred items.

Surveillance in Category I areas of occupied facilities include CCTV monitoring by security personnel and implementing the two-person rule. Areas of the facility in which Category I quantities of SNM will be left unattended must be within an MAA and must be equipped with intrusion detection. Commonly used detection systems include balance-magnetic switches on doors, motion detection, and continuous CCTV.

Additionally, automated surveillance systems can be employed in storage vaults to provide redundant assurance of material integrity. Under certain circumstances, these systems may reduce inventory frequency requirements based on guidance issued by the NRC. Automated systems include position integrity monitoring (e.g., presence switches, digital imaging) and attribute confirmation (load cell, radiation/heat measurement).

MBAs will be defined around specific processes and, therefore, over a specific geographic area. Processes that will normally be operated together will be contained within a single material balance area to facilitate measurement and control of nuclear material. The MBAs will be established to compartmentalize processes and activities. The design of processes and related equipment will be arranged so that the physical inventory in each material balance area can be conducted independently, and that verification measurements can be made as required.

Accountability measurement systems will be installed in the process equipment, located in the process area, or located in an entirely separate laboratory area. Facility design will address concerns such as vibration, temperature, and space appropriate to the measurement system being used. A measurement control system will be implemented and documented.

One of the design goals of the fabrication facility will be to minimize holdup of nuclear material. Design elements intended to minimize holdup include HEPA filters at the glovebox, which will prevent the accumulation of nuclear material in the exhaust plane. Portable holdup measurement equipment and trained personnel will be available when radiation readings or inventory differences indicate the need to measure holdup. In addition, a program will be established to measure holdup at regularly scheduled intervals.

2.3.4. International Inspections. Because of anticipated future international treaty obligations, the fabrication facility will be subject to inspection of its plutonium and uranium inventories by international organizations such as the IAEA. The IAEA is responsible for independently verifying that material has not been diverted for non-peaceful purposes.

Inspections are anticipated to take place within the facility areas where NDA measurements of the nuclear material are made. If such inspections are required, a separate room for secure storage of inspection instrumentation may be necessary. To further accommodate IAEA inspections, the surplus fissile material storage and processing activities at the fabrication facility will be designed to accommodate international and bilateral transparency requirements whenever possible.

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2-5. "Flood Protection, (1.10. (this has been withdrawn in July 1981).

2-6. USNRC Guide 3.16, "General Fire Protection Guide for Plutonium Processing and Fuel Fabrication Plants," January 1974.

2-7. National Fire Protection Association Fire Codes, Battery Park, Quincy, MA, 02269.

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2-9. USNRC Guide 1.75, "Physical Independence of Electrical Systems," September 1978.

2-10. USNRC Guide 3.34, "Assumptions Used for Evaluating the Potential Radiological Consequences of Accidental Nuclear Criticality in Fuel Processing Plant," April 1977.

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2-12. USNRC Guide 3.57, "Administrative Practices for Nuclear Criticality Safety at Fuels and Materials Facilities," October 1986.

2-13. ANSI/ANS 8.12, "Nuclear Criticality Control and Safety of Plutonium-Uranium Fuel Mixtures Outside Reactors," La Grange Park, IL, 1987.

2-14. USNRC Guide 3.12 ,"General Design Guide for Ventilation Systems of Plutonium Processing and Fuel Fabrication Plants," August 1973.

2-15. ASHRAE guidelines, American Society of Heating, Refrigeration and Air-Conditioning Engineers, 1791 Tullie Circle, NE, Atlanta, GA 30329.

2-16. Code of Federal Regulation, 10 CFR 73. "Physical Protection of Plant and Materials."

2-17. DOE Order 5633.3B, "Control and Accountability of Nuclear Materials.

2-18. "Barrier Technology Handbook," Sandia National Laboratories

2-19. DOE Order 5632.7, "Protective Force.

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3. SITE MAP AND LAND USE REQUIREMENTS

This section describes both the proposed MOX FFF location at the Savanna River Site (SRS) and a representative generic preconceptual MOX FFF.

3.1. Site

The SRS facility is located in the southern portion of the state of South Carolina. The proposed MOX FFF location, F Area, is approximately 18 miles southeast of Aiken, South Carolina, and 22 miles east of Augusta, Georgia, as shown in Fig. 3-1. The proposed location of the MOX FFF is adjacent to the new planned Actinide Processing and Storage Facility (APSF). Support functions would be provided by either new or existing facilities. The F Area complex is located adjacent to other support facilities and site areas (see Fig. 3-1). Figure 3-2 illustrates the proposed location of the new MOX FFF in F Area. The Pit Disassembly and Conversion Facility (PDCF) may also be constructed at SRS, and the proposed PDCF facility arrangement is also shown in Fig. 3-2. For EIS purposes, locating the MOX FFF as shown in Fig 3-2 provides a bounding representation for construction purposes and is thus the basis for this data call.

3.2. MOX Facility

To implement the DOE MOX mission at SRS, a new facility would be constructed. The preferred location is adjacent to the APSF in the F Area. The facility would be designed and operated by a private contractor (or consortium of organizations) and, therefore, the exact facility arrangement (size, actual MOX processes, staffing, degree of automation, etc.) is unknown at this time. This private contractor will be responsible for the detailed design, licensing, construction and operation of the MOX FFF as detailed in the program acquisition strategy (PAS, Ref. 3-1). This data report includes a preconceptual MOX facility as shown in Figs. 3-3.1 and 3-3.2. The preconceptual layout is consistent with other contemporary MOX FFFs and is described in the next Section. The assumptions used for the preconceptual layout are summarized in Appendix A. This generic facility provides all of the identified MOX manufacturing functions (see Appendix C for a list of these functions).

3.2.1. Generic MOX Facility. The generic MOX facility shown in Figs. 3-3.1 and 3-3.2 is a conceptual design based on an amalgamation of various previous MOX facility designs and requirements. (Refs. 3-2 through 3-11). To implement a MOX FFF, a main complex and several support buildings are required. As envisioned, the preconceptual generic layout is composed of a two-story, hardened, reinforced concrete structure. The basement level is intended to be underground, with only the first floor at grade level. This type of building arrangement provides optimal responses to seismic and other structural challenges. The compact layout offers some economies in relation to materials and construction costs. The walls, floors, and roof are expected to be fabricated out of approximately 18-in.-thick (~46-cm) reinforced concrete. Depending on the final design and corresponding hazards analysis, these wall and ceiling thicknesses may actually be greater, but this value is considered adequate for approximation purposes.

Not directly shown on Figs. 3-3.1 and 3-3.2, but implicit in the design, is a solid reinforced concrete ceiling above the MOX fuel fabrication line. This creates a totally sealed area for the MOX fabrication equipment area with an equipment chases or service area between the facility roof and the MOX process line ceiling. The equipment "rooms" shown in the MOX fabrication area will most likely be constructed of steel (roof and walls), and the floors will be coated concrete. In many cases, these steel walls will be constructed in such a way that shielding material (e.g., lead) can be inserted to reduce radiation exposure levels. These "steel rooms," which contain the glovebox assembly lines, are then maintained at a slightly negative pressure to prevent any airborne contamination from leaving the MOX production areas. The gloveboxes are maintained at a slightly lower pressure than the steel enclosure rooms.

All process lines (HVAC, process cooling and heating, sintering oven exhaust gas, instrumentation and electrical feeds, etc.) would be routed above the process area in the equipment chase area. The vault and MOX pellet fabrication areas are in additionally hardened areas (i.e., a secondary shell for additional protection). The facility is arranged so that materials "flow" through it, and in particular, the MOX fabrication lines are intended to move material from one process to another in a straight line (with adequate storage at each step to allow for process requirements). Incoming PuO_2 would be transferred by underground tunnel from the APSF. Provisions may be included in the underground tunnel arrangement so that safe secure transport (SST) vehicles could be received in the underground receiving and unloading area. However, it is assumed, at this time, that all shipments would first be received at the APSF and then transferred to the MOX FFF. The PuO_2 will be shipped in SST vehicles if the PDCF is not located at SRS. It is expected that the DUO_2 and UO_2 (D/UO_2) will be shipped in regular truck or truck-trailer combinations. If the PDCF is co-located at SRS, then it is expected that the PuO_2 would be transferred using underground tunnels as shown in Fig. 3-2 ({PDCF to APSF and APSF to the MOX FFF). The PuO_2 material is then assayed upon receipt at the MOX FFF and accountability requirements are confirmed before to placement in appropriate underground vaults. The SRS MOX FFF has a smaller vault and receiving area because it is anticipated that the vault capacity in the APSF would be used to store most of the PuO_2 being used for fuel fabrication. The MOX FFF is designed to process 3.5 MT of Pu/yr, so factoring in the APSF vault, it is not expected that the MOX FFF would have more than 1 ton of PuO_2 in plant's vault at any one time. The D/UO_2 would be stored in the same vault, primarily to facilitate transfer to the MOX pellet fabrication area, as well as to enhance safeguards/accountability of this material. [Note: In some designs, this material is stored in open warehouse areas as it is not considered hazardous by itself. However, it must be stored in "conditioned space" to assist in the prevention of self-amalgamation, which would impair its use in the MOX process.] The APSF vault also provides surge capacity if it is necessary to store additional quantities of PuO2. The PuO_2 and D/UO_2 are conveyed from the vault to the MOX pellet fabrication lines by secure elevators.

The basement area contains the general shipping and receiving docks, the general warehouse area (used to store facility supplies), the LLW storage area, the standby generators, the HVAC systems, process gas and waste processing/treatment areas, certain office facilities, the fuel bundle assembly component storage area, the fuel pin fabrication area, and the fuel bundle storage and shipping areas. It is intended that the MOX fuel be shipped by SST.

A separate warehouse is provided to store items that do not need to be readily available within the facility (e.g., empty UO_2 shipping drums, MOX fuel shipping containers, and various expendables).

The MOX pellet fabrication process is arranged in two lines. It is intended that these lines be operated independently (e.g., PWR and BWR fuel pellet fabrication and pin loading on separate lines) or alternately as redundant components so that process material can be interchanged between the lines. The actual process arrangement will be determined by the selected MOX facility designer/operator. Space has been allocated for an additional line of unknown fuel type to accommodate future MOX programmatic needs.

It is understood that the MOX facility will be regulated by the NRC. This implies that the SNM will fall under NRC regulatory oversight once it arrives at the facility. It is unlikely that SNM material transfers will routinely be bi-directional; that is, once the material is received by the facility, it will remain under NRC jurisdiction. Provisions have been made to provide for both IAEA and NRC office areas for regulatory compliance oversight functions. Provisions have been made for IAEA inspections for both incoming and outgoing materials as well as for independent IAEA office areas.

The building HVAC is arranged so that the MOX pellet fabrication areas are maintained at the lowest pressure. In this way, any gaseous or suspended particulate matter leaks are contained and appropriately filtered. A dual-train HVAC system is provided into a dual exhaust stack (housed within a common support structure). It is envisioned that the exhaust stack will be designed for approximately a 25 to 30 ft (~8 m) elevation discharge (a higher stack, ~25 m, may be necessary as a result of detailed accident analysis). Both incoming (fresh air makeup) and outgoing exhaust air would be filtered. Radiation monitors would monitor exhaust gases and place the system in a filtered recirculation mode in the event of a release type accident.

It is expected that the MOX facility would receive electricity from two independent outside sources. Critical systems (primarily HVAC exhaust fans, radiation and criticality instrumentation, process lighting, and security and manufacturing equipment would be powered from UPS systems to prevent process interruptions caused by momentary losses of outside electric power. Standby generators would be provided to supplement off-site power and allow for an orderly shutdown in the event of loss of outside AC power. Critical systems would continue to be powered by the UPS/generators until off-site power was restored. Facilities are provided for material accountability and safeguards and security functions.

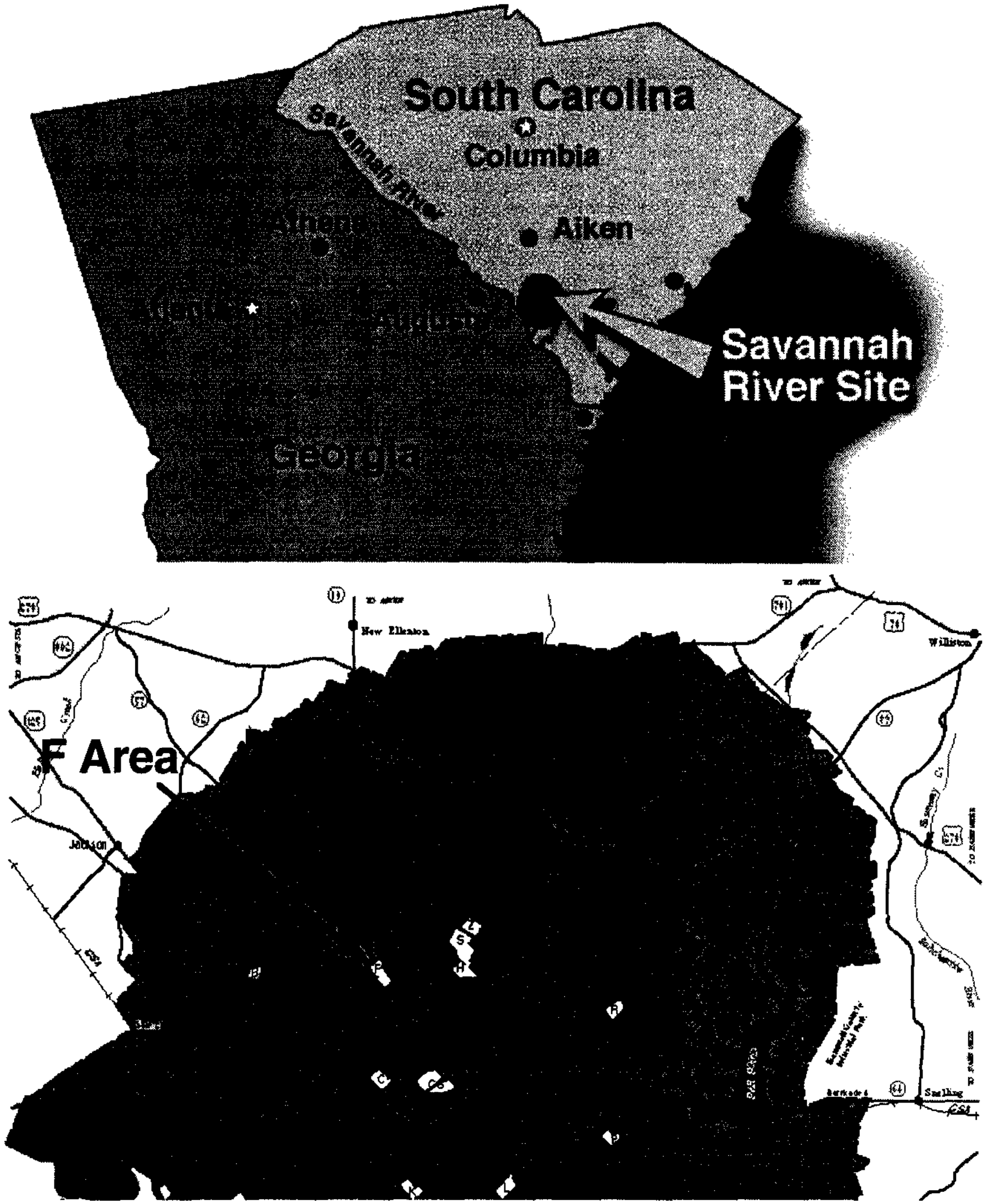


Fig. 3.1. Savanna River Site and MOX FFF Location

Savannah River Site
F Area MOX Mission Facilities

Not to Scale / Source: LANL Sketch

NOTES:

1. Training located in the H area
2. Waste processing at this site and S&Z areas
3. Warehousing areas throughout site

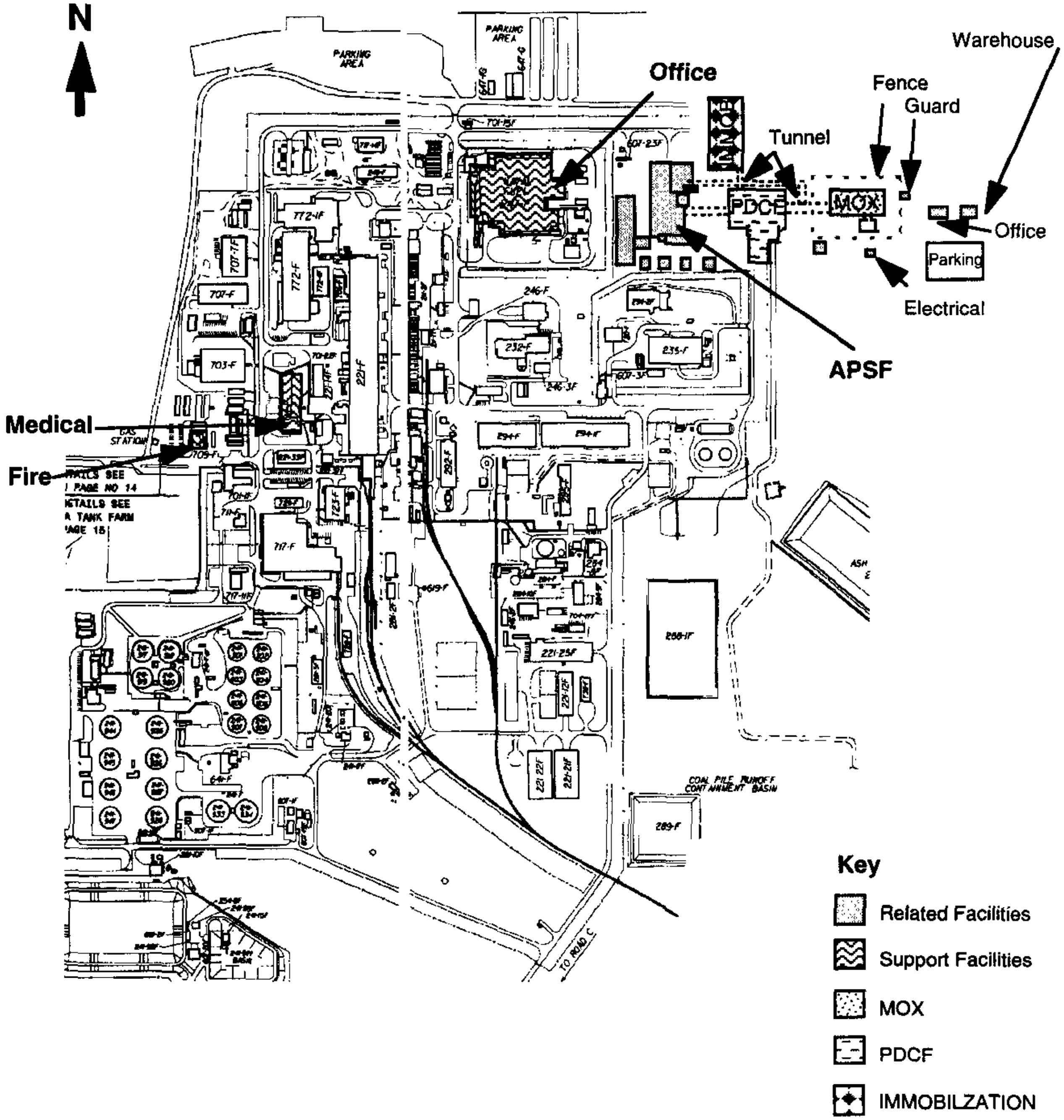
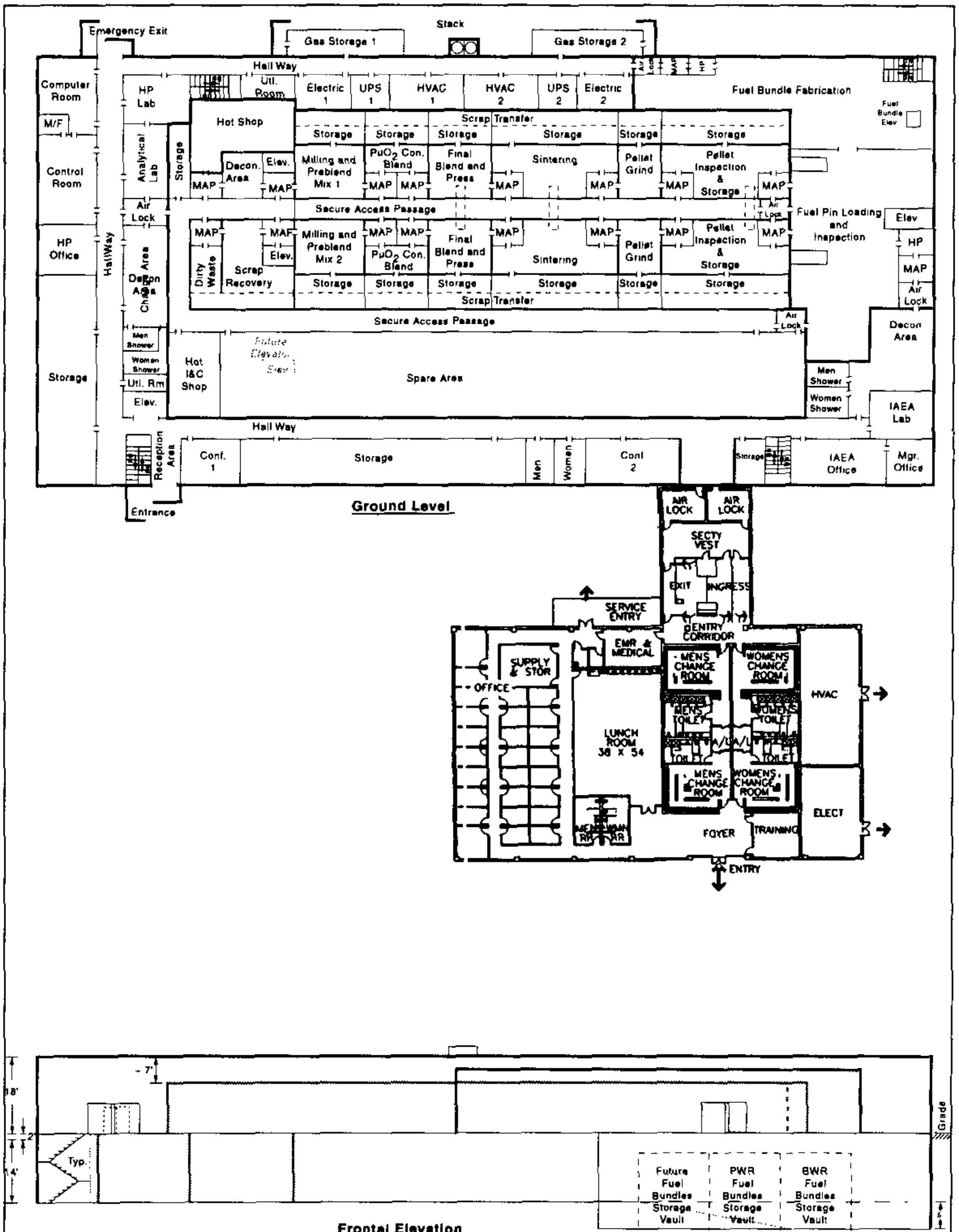


Fig 3.2. F Area MOX FFF location and support facilities



MAP = Material Accountability Program and Safeguards and Security Functions (actual arrangement may vary)

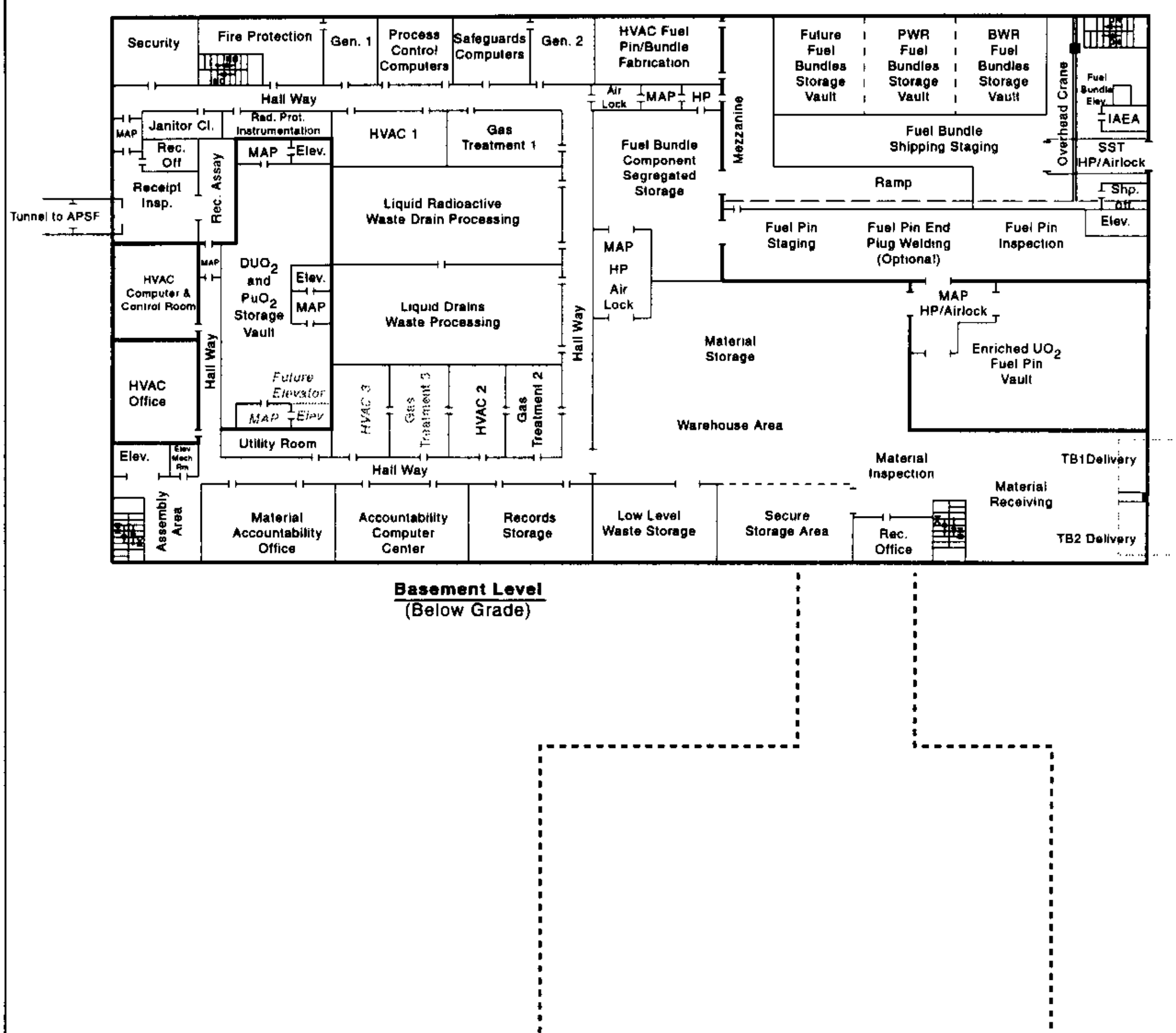
Draft - Subject to Revision

SRS Pre-Conceptual MOX Facility (Generic)		
Size: ~150' x ~320' ~120,000 ft.²	Levels: 2 Ground	Construction: Reinforced Concrete (Hardened)
Date: 2/23/98 Time: 2:20 pm	Scale: Not to Scale	Source: LANL Sketch By: JH/KO - TSA-10/11

NOTES:

1. Not shown, 10-20,000 ft² office facility for related MOX mission support (e.g. training, scheduling, engineering, personnel, etc.), and 20,000 ft² warehouse area for storage of shipping containers.
2. Category 1 Building
3. Additional security facilities may be required. See applicable site plan.
4. —— Structurally Hardened Wall, —— Shield Wall
5. Room/area sizes are approximate, actual arrangement will vary

Fig. 3-3a. SRS Pre-Conceptual Generic MOX Facility -Ground Level



MAP = Material Accountability Program and Safeguards and Security Functions (actual arrangement may vary)

Draft - Subject to Revision

SRS Pre-Conceptual MOX Facility (Generic)		
Size: ~150' x ~320' ~120,000 ft.^{2}	Levels: 2 Basement	Construction: Reinforced Concrete (Hardened)
Date: 2/23/98 Time: 2:20 pm	Scale: Not to Scale	Source: LANL Sketch By: JH/KO - TSA-10/11

Fig. 3-3b. SRS Pre-Conceptual Generic MOX Facility -Basement Level

The generic layout provides a hardened structure with additional hardening around SNM storage vaults and fuel manufacturing areas. This is, in essence, a shell-within-a-shell concept. Integral to the MOX mission are additional office and warehouse facilities needed for support functions as shown in Fig. 3-3. It is estimated that the office facility would need to be between 10,000 and 20,000 ft^2, depending on actual mission needs and existing support infrastructure. The warehouse area would need to be about 20,000 ft^2 and would be used to store UO_2 and MOX fuel shipping containers, as well as other support materials. This warehouse would be of the conventional prefabricated metal building style or an equivalent structure. Parking, an incoming electrical substation and guard facilities would also be provided as shown on Fig. 3-3. These infrastructure requirements are tabulated in Table 3-1.

3.2.2. Shared Facilities. There are some existing facilities that would or could be used to support the MOX mission. However, since the MOX facility may be operated by a different contractor organization than the SRS site operator (currently Westinghouse Savannah River Corp.), the degree to which some of these facility functions may be commingled or otherwise shared will depend on contractual (business) relations. For the EIS, it is assumed that existing facilities will be available to support the MOX mission to the extent that they may be shared/used by the MOX FFF operator. In this regard, it is expected that site-wide security (provided by the DOE contractor) and emergency services (fire, medical, environmental, etc.) would be provided by the DOE site contractor.

Table 3-2 identifies construction related area requirements. A number of these construction areas are temporary and would not be used after the facility commenced operations (e.g., construction laydown areas and construction worker parking). The F Area has sufficient free areas so that ample areas for these functions are available.

TABLE 3-1. SRS F Area New MOX Facility Data

Building Structures	Status[a]	Footprint ft^2 total area = { }[b]	Number of Levels	Special Nuclear Materials	Construction Type
Process buildings	New (Generic)	~70,000 1st flr ~44,000 bsmt {114,000 ft^2}	2	SNM	Reinforced concrete
Warehouse	New	20,000	1	no	Steel building
Product Storage facilities -D/UO_2 -PuO_2 -New fuel	Internal to MOX Facility	 ~1600 ~4800 ~4600	1 1 1 1	SNM	Reinforced concrete
Waste storage facilities	Internal to MOX FFF	~800	1	possible	Reinforced concrete
Support facilities -parking -staging areas -personnel processing	New	 60,000 70,000 Admin. Bldg.	varies	no	 Asphalt gravel Steel/block
Administration building	New	10,000 1st flr 10,000 2nd flr {20,000}	2	no	Steel/block
Utilities switchyard	New	~5,000	1	no	Concrete Pad
Generator(s) -new	In MOX facility	~400	1	no	Reinforced concrete
Security admin./access control	New	~5,000	1	no	Reinforced concrete hardened
Fire station	Existing located in F Area	~8,000	1	no	F Area
Emergency medical	Existing located in F Area	~6,000	1	no	F Area

Notes:

a. Existing facilities. However, some modifications or renovations may be required to implement the MOX mission.

b. Symbols: ~ = estimated area, { } = total area, where appropriate.

TABLE 3-2. SRS F Area MOX Facility Construction Area Requirements

Function	Area (ha)[a] or Distance (km)
Total disturbed construction area (ha)	20
Construction Laydown Area (ha)[b] (including spoils, topsoil, etc.)	2 (see Fig. 3-3)
Warehousing Area (ha)[c] [Note: new warehouse for shipping container storage (UO_2 and new fuel) will be required - 20,000 ft^2 estimated size]	existing for interim use until MOX FFF warehouse is available ~0.2
Product Storage Area[d] (ha)	0.1
Waste Storage Area (ha)	1
Security Area[e] (ha)	3
New Parking lots (operations) (ha)	2
Temporary Parking lots[f] (construction) (ha)	2
New roads[g] (km)	2

Notes:

a. 1 ha = 2.471 acres (1 acre = 43,560 ft^2, 1 ha = 107,636.7 ft^2), 1 mile = 1.609 km.

b. F Area has ample laydown area for construction related activities. Actual requirements will depend on construction scheduling and sequencing.

c. Warehouse facilities are located in Area F and can be re-used for the MOX mission. Ample laydown area exists for receiving MOX facility materials.

d. Product storage for fuel bundle storage is internal to the MOX facility. Three storage racks, vertical hanging, are provided for fuel bundle storage. Bundle spacing will be adequate to prevent criticality.

e. Security are existing inside F Area, see Fig. 3-2. A new NRC security area will be constructed around the MOX FFF.

f. Temporary parking will be established in F Area adjacent to the MOX FFF site.

g. No new roads other than access roads for new and temporary facilities will be required, see Fig. 3-2.

3.3. References

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3-10. D. Hass, A. Vandergheynst, J. V. Vliet, R. Lorenzelli and J. L. Nigon, "Mixed Oxide Fuel Fabrication Technology and Experience at the Belgonucleaire and CFCa Plants and Further Developments for the Melox Plant," Nuclear Technology, Vol. 106, April 1994.

3-11. J. van Dievort, H. Bairot, G. Le Bastard, H. Pekarek and H. Roepenack, "MOX Fuel and its Fabrication in Europe."

4. PROCESS DESCRIPTIONS

4.1. Background

The generic MOX fuel fabrication flowsheet for disposition of 3.5 metric tons (MT) plutonium metal per year, based on the use of depleted (or natural, depending on production/fuel design requirements) uranium for fuel fabrication, is shown in Figs. 4-1.1 and 4-1.2. The values shown in these figures are representative of the expected ranges for a MOX FFF of this size. The 3.5 MT plutonium metal per year is compatible with the PDCF production rate. The total heavy metal production (uranium and plutonium) is based upon producing twice the amount of PWR as BWR fuel (Ref. 4-1) where the PWR enrichment is 4.29 wt% Pu and the BWR enrichment is 2.97 wt% Pu, based upon a weapons grade plutonium isotopic distribution (~94% fissionable). Enriched UO_2 fuel rods or pellets may be required as part of the fuel rod and bundle fabrication, if bundle design requires a mix of MOX and enriched UO_2 rods or pellets. The maximum amount of enriched UO_2 required is assumed not to exceed twice the MOX fuel. The amount of enriched uranium fuel required at the MOX fuel fabrication plant will depend on the actual fuel bundle designs, which are not yet established.

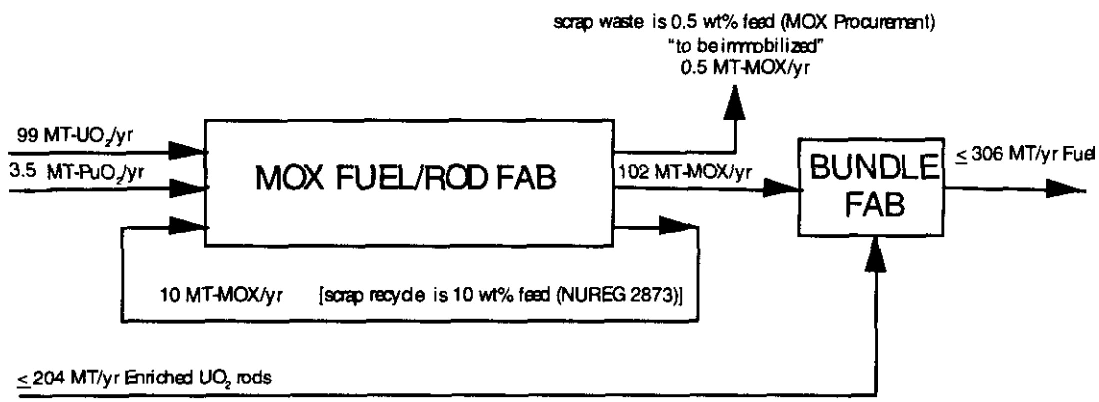
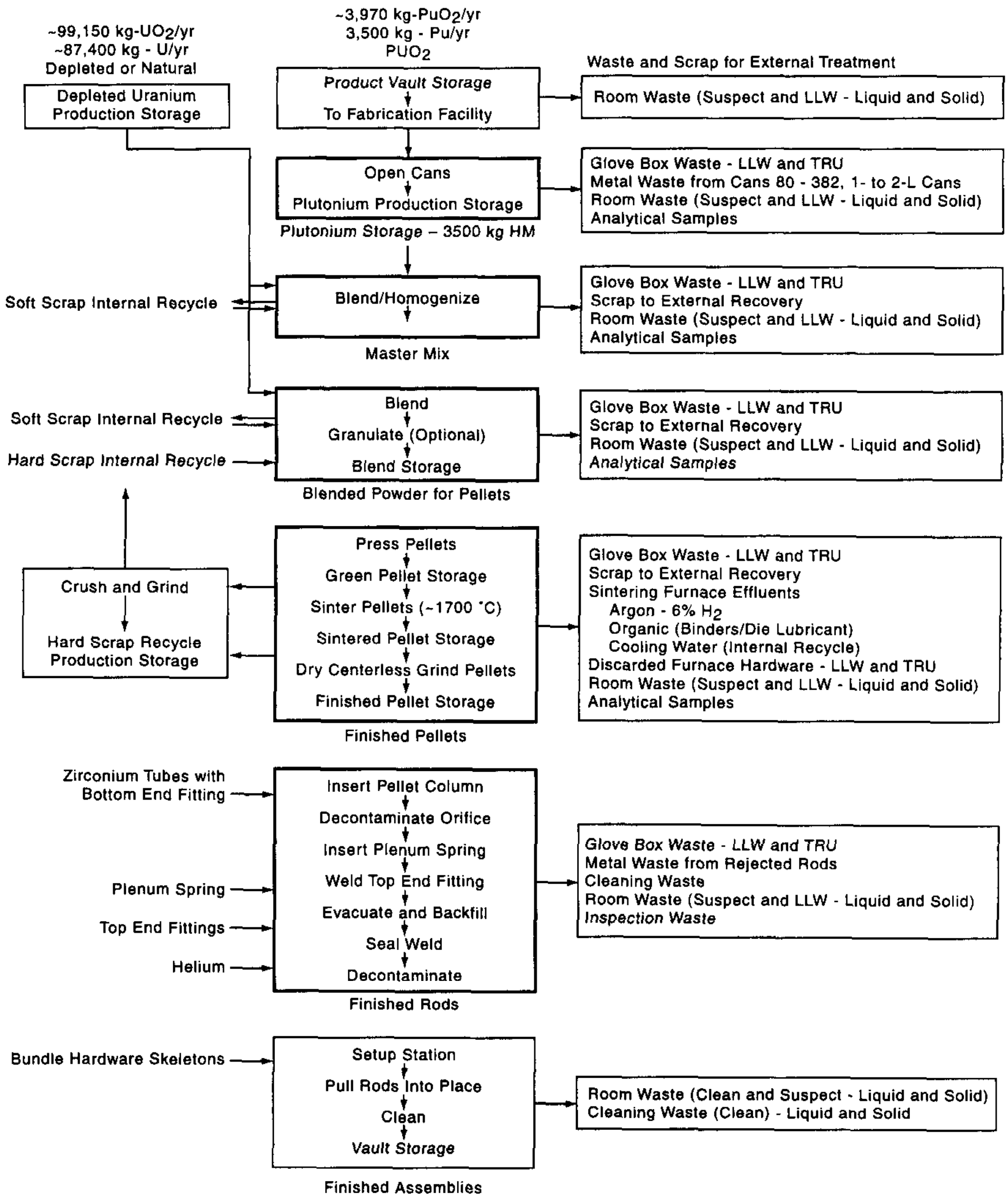


Fig. 4-1.1. Generic MOX flowsheet based on 3.5 MT Pu/yr.

A more detailed material balance including the individual process steps can be found in the hazards analysis section of this report.

Although (1) the use of depleted uranium for MOX fuel fabrication and (2) preparation of twice the amount of MOX for PWRs than BWRs have been selected as the most prudent baselines for establishing the facility material balances, other baselines can be imagined. For instance, it is possible to fabricate MOX fuel from natural rather than depleted uranium; however, as shown in Fig. 4-1.2 natural uranium would require the production of more MOX fuel than depleted uranium. This is due to matching the fissionable concentration in fuel regardless of its



NOTE: Heavy Borders are Glove Box Process Operations

Fig. 4-1.2. MOX fabrication process and waste streams.

constituents. Consequently, the use of natural uranium would demand a larger disposition program including the number of reactors, required and therefore would increase the impact on the existing United States uranium enrichment market. It also could be assumed that all BWRs, and no PWRs, would be used for disposition, which would additionally increase the MOX production as shown in Figure 4-1.3. But this would not be a prudent requirement to impose on the disposition program, since more PWRs exist in the United States than BWRs.

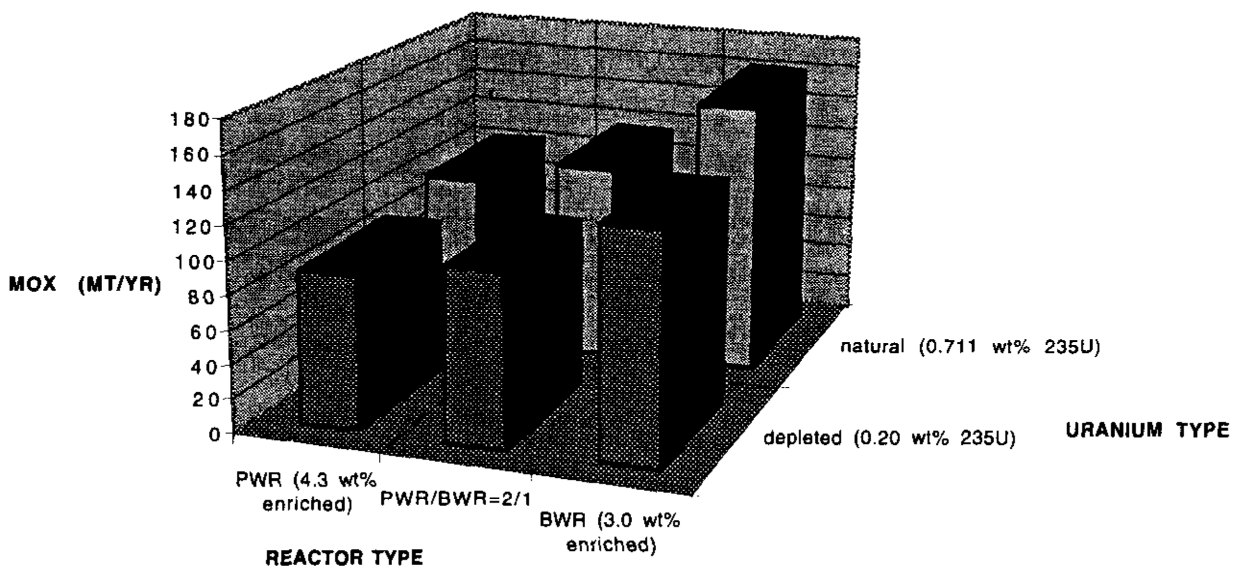


Fig. 4-1.3. MOX production based on 3.5 MT Pu/yr for alternative scenarios

The production of MOX for the disposition program can be compared with the existing production of enriched uranium in the United States. The current United States production of enriched uranium is estimated as follows (Ref. 4-2):

US	85% of needs for 99 reactors	0.85(99) =	84.2 reactors
Europe	50-100% of needs for 10 reactors	0.75(10) =	7.5 reactors
Japan	70-100% of needs for 39 reactors	0.85(39) =	33.2 reactors
Korea	100% of needs for 4 reactors		4.0 reactors
Taiwan	100% of needs for 6 reactors		6.0 reactors
Mexico	100% of needs for 2 reactors		2.0 reactors
Total			136.9 reactors

The average power per reactor is slightly less than 1,000 MWe, or approximately 900 MWe. A majority of existing reactors operate in ranges from 800-1,100 MWe; however, a number of smaller reactors are still in operation.

It is assumed a 1,000 MWe reactor core is composed of approximately 100 MT of fuel, and one-third of the core is replaced each year.

Total fuel = 136.9(1/3)(100 MT)(900/1000) = 4107 MT UO_2 fuel.

Consequently, the MOX share of the current United States enriched uranium production is approximately

Fraction MOX = 100%(100 MT MOX)/(4107 MT UO_2) = 2.4%.

4.2. Introduction

Fuel fabrication has been divided into the seven different processes listed below.

1. Materials receiving and storage
2. Feed material preparation
3. Fuel pellet fabrication
4. Fuel rod fabrication
5. Fuel bundle assembly
6. Materials recycle
7. Waste management

The fuel fabrication process consists of blending PuO_2 and UO_2; fabrication of fuel pellets; fabrication of fuel rods; assembly of fuel bundles; recycling plutonium-bearing scrap and materials from pellets, rods, and bundles that do not meet requirements; and management of wastes generated throughout the fuel fabrication process.

The overall fuel fabrication process flow diagram is shown in Fig. 4-2. More detail is shown in flow diagrams for each of the seven processes.

4.3. Materials Receiving and Storage

4.3.1. Materials Receiving and Storage: Function. In the materials receiving and storage process, all important fuel fabrication supplies are received, inspected, and sampled; accountability is established; and the materials are stored, observing criticality controls on plutonium and surrounding materials. There are several in-process storage locations distributed throughout the seven processes. Figure 4-3 shows the process flow diagram of the processes described above.

4.3.2. Materials Receiving and Storage: Feeds. Feed materials include PuO_2, UO_2 from natural or depleted uranium, depletable neutron absorbers, depletable neutron absorber rods, enriched UO_2 fuel rods, and other miscellaneous materials such as lubricants used in pressing pellets, process gases, and fuel pin and bundle hardware. Also, chemicals used in the analyses of materials for treating and recycling wastes, and cleaning solvents for finished rods and bundles are received and stored. The PuO_2 is stored in a vault.

4.3.3. Materials Receiving and Storage: Products. Process materials are stored properly and inspected to ensure that they meet specifications. Appropriate steps are taken to ensure the security of plutonium oxide and compliance with criticality requirements. Damaged or rejected materials are held pending final disposition.

4.3.4. Materials Receiving and Storage: Utilities Required. Utilities required for the process are electricity for lighting, instrumentation, MC&A equipment computers, bar code readers, ventilation, sanitary and potable water, and powered equipment such as cranes, movable racks, and forklifts.

4.3.5. Materials Receiving and Storage: Chemicals Required. No chemicals are required other than the materials themselves.

4.3.6. Materials Receiving and Storage: Special Requirements. The primary objectives of receiving and storage are that the materials be stored in a safe manner and in accordance with appropriate guidelines; that criticality safeguards be adhered to rigidly; and that appropriate measures be taken to guard against diversion of plutonium to unauthorized use. In addition, required MC&A measurements will be adhered to for SNM, and all materials will be procured, received, inspected, and stored in accordance with strict QA practices and requirements. ALARA principles will be adhered to for the protection of storage area workers.

4.3.7. Materials Receiving and Storage: Wastes Generated. Normally, only office, sanitary, and packaging wastes are generated. Additional wastes may be generated if a failed shipping container were to be received. The level of waste generated under this situation is not expected to be significant and would primarily consist of decontamination materials, similar to the decontamination materials generated during normal facility operations. Thus, this additional material, if any, would not cause a measurable change in the total wastes reported herein because the number of failed shipping containers received, if any, would be very small.

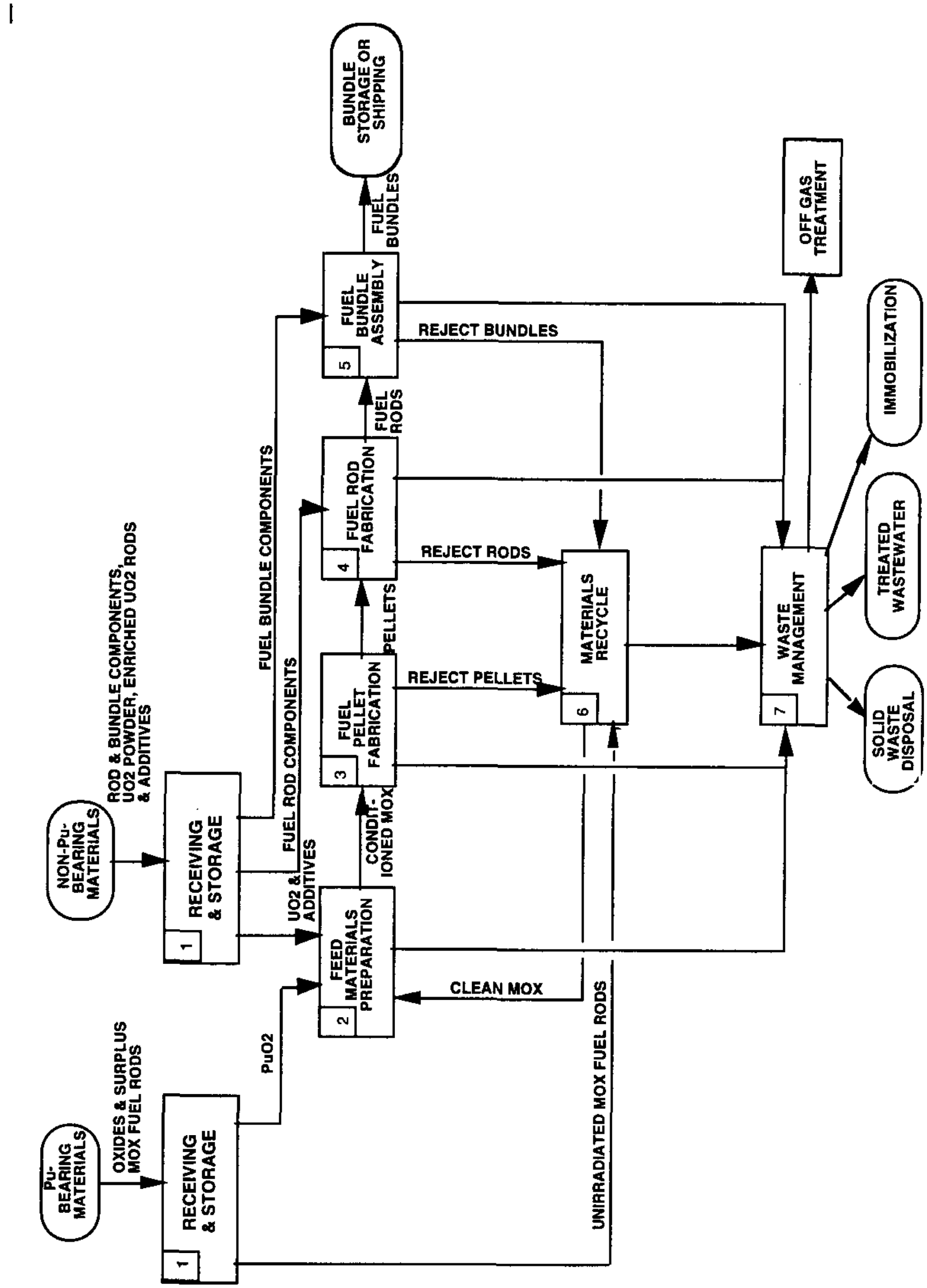


Fig. 4-2. MOX fabrication overall process flow diagram.

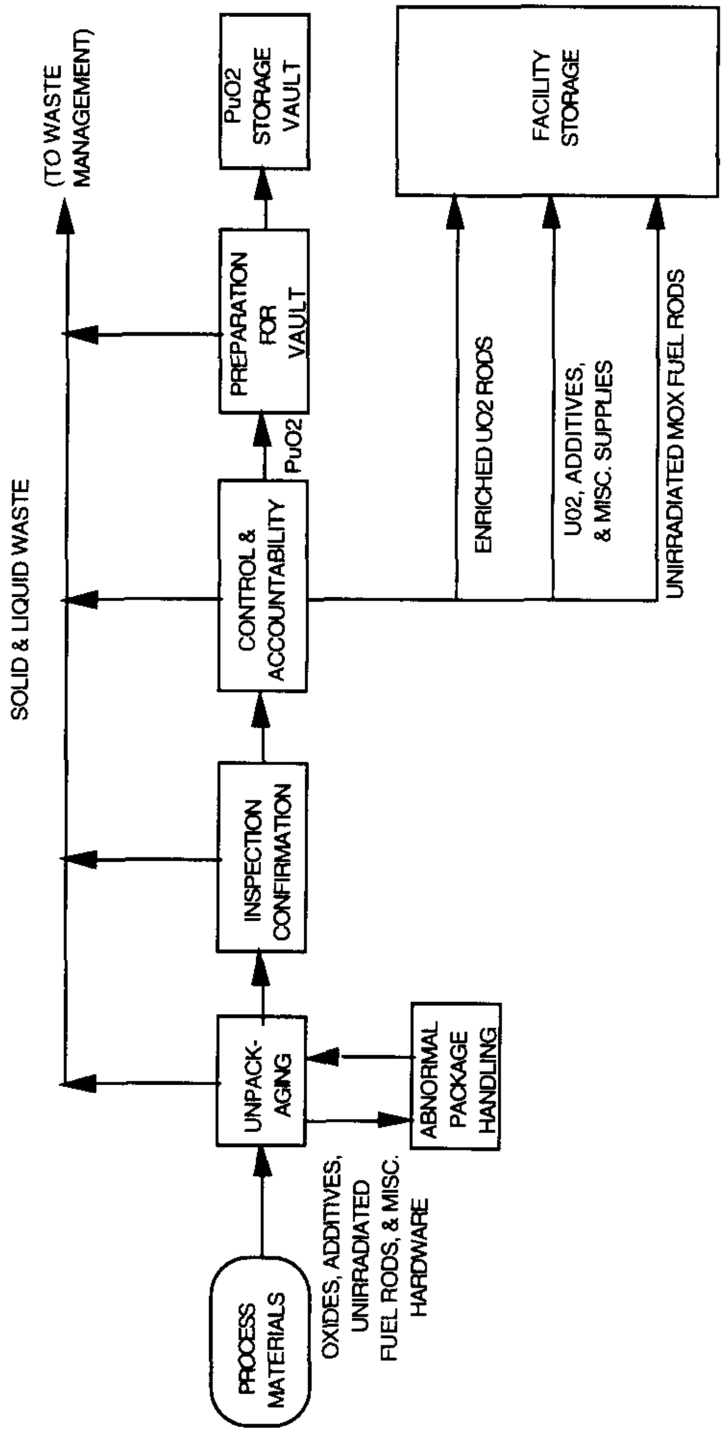


Fig. 4-3. Receiving and storage process flow diagram.

4.4. MOX Feed Materials Preparation

4.4.1. Feed Materials Preparation: Function. PuO_2 from receiving and storage or the materials recycle process is milled and screened to specification in batch lots. Any oxide not meeting specifications is recycled and remilled. Lots are then blended to ensure consistency through extended periods of production. Special blending may be necessary to maintain consistent impurity concentration and plutonium isotope composition. The PuO_2 is then stored until needed. Depleted or natural uranium oxide powder to be blended with plutonium oxide powder is received from off site in a ready-to-use condition and is stored for later use.

As needed, UO_2, PuO_2, recycled MOX scrap, and depletable neutron absorber (if required) are removed from storage and placed in feed bins. Each is first weighed out in proper proportions to form a batch and is then placed in a mill/blender combination to achieve homogeneity. Portions from several batches are separated out, cross blended, and then reblended by passing through the mill/blender again to form a large lot. The powder is agglomerated to form it into a free-flowing press feed and is placed into storage. Batch size is determined by criticality safety limits on mass, but uniformity over much larger process units is desired to minimize sampling and optimize product consistency. All operations are performed in gloveboxes. These processes are depicted in Fig. 4-4.

Milling is the standard method for adjusting particle size. Blending is a necessary process to mix different powders together and to ensure uniform distribution (homogeneity) of plutonium in the finished fuel. Both operations have been used for many years in the fabrication of standard fuels for American reactors and for the manufacture of MOX fuels overseas.

4.4.2. Feed Materials Preparation: Feeds. Feeds for this process include PuO_2, UO_2, depletable neutron absorbers (if required), and other additives such as lubricants for pressing and a powder handling agent.

4.4.3. Feed Materials Preparation: Products. The products are batches of MOX powder in proper proportions ready for fabrication of finished pellets.

4.4.4. Feed Materials Preparation: Utilities Required. Utilities used in this process include electricity for lighting, instrumentation, MC&A equipment, ventilation and gas control through the glovebox(es); electricity to power feeders, milling, blending, and agglomeration equipment; and sanitary and potable water.

4.4.5. Feed Materials Preparation: Chemicals Required. Chemicals that may be required in this process include zinc stearate as a pressing lubricant and polyethylene glycol to aid powder handling.

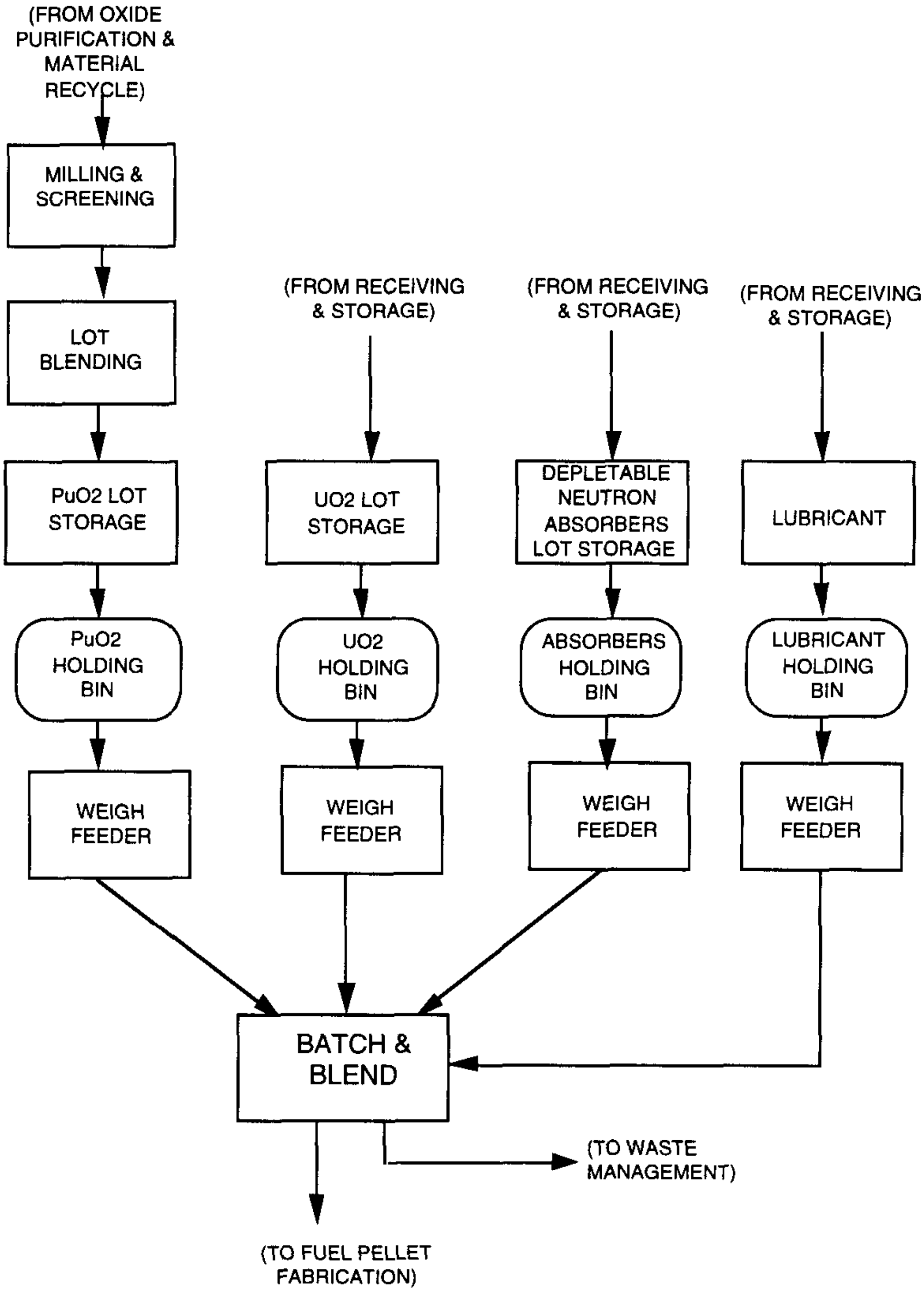


Fig. 4-4. Feed material preparation process flow diagram.

4.4.6. Feed Materials Preparation: Special Requirements. Processing and storage must observe strict criticality controls, safeguards against diversion of plutonium, controls designed to preclude any ingestion of plutonium powder, and any other applicable guidelines.

4.4.7. Feed Materials Preparation: Wastes Generated. Wastes generated by this process include contaminated gloveboxes, milling machines, and powder storage containers; other waste including contaminated operator clothing such as gloves, wipes, and shoe covers; used ventilation system filters; hydraulic oil from agglomerators; worn-out milling media; and used analysis chemicals. Glovebox sweepings consist of reject plutonium and uranium oxides, with impurities such as depletable absorbers, brush hair, lint from wipes, and oil.

4.5. Fuel Pellet Fabrication

4.5.1. Fuel Pellet Fabrication: Function. The process for fabricating fuel pellets involves receiving conditioned MOX feed, pressing the pellets, loading the pellets into sintering boats, and storing them until needed. Rejected pellets are sent to materials recycle. After pressing, all storage between process steps is from in-line surge capacity and is not at a separate storage location. After the boats are placed in the sintering furnace, they are sintered in an atmosphere of argon with 6 mole% hydrogen to control the oxygen-to-metal ratio. The pellets are removed from the furnace, inspected for conformance to dimensions, density, homogeneity, and stoichiometry requirements, and are held in in-line storage until needed. Rejected pellets are sent to be recycled. Sintered pellets are then ground to dimension and are inspected for dimensional conformance, purity, and fissile content. Rejected pellets are sent to be recycled.

Acceptable pellets are placed in storage until needed. All operations are performed in sealed gloveboxes. Sintering ovens are also sealed and all off-gases are collected and processed. The process is depicted in Fig. 4-5. This process for fabricating fuel pellets has been in use for over 30 yr.

4.5.2. Fuel Pellet Fabrication: Feeds. Feeds for this process include fuel batch mixtures.

4.5.3. Fuel Pellet Fabrication: Products. The products are finished fuel pellets that are ready for loading into fuel pins.

4.5.4. Fuel Pellet Fabrication: Utilities Required. Utilities used in this process include electricity for lighting, instrumentation, MC&A equipment, ventilation and gas control through the glovebox(es); electricity for powering presses, grinders and furnaces; sanitary and potable water; and industrial cooling water for the sintering furnaces. Presses and furnaces consume significant amounts of power and produce large amounts of waste heat that must be rejected by an onsite cooling system.

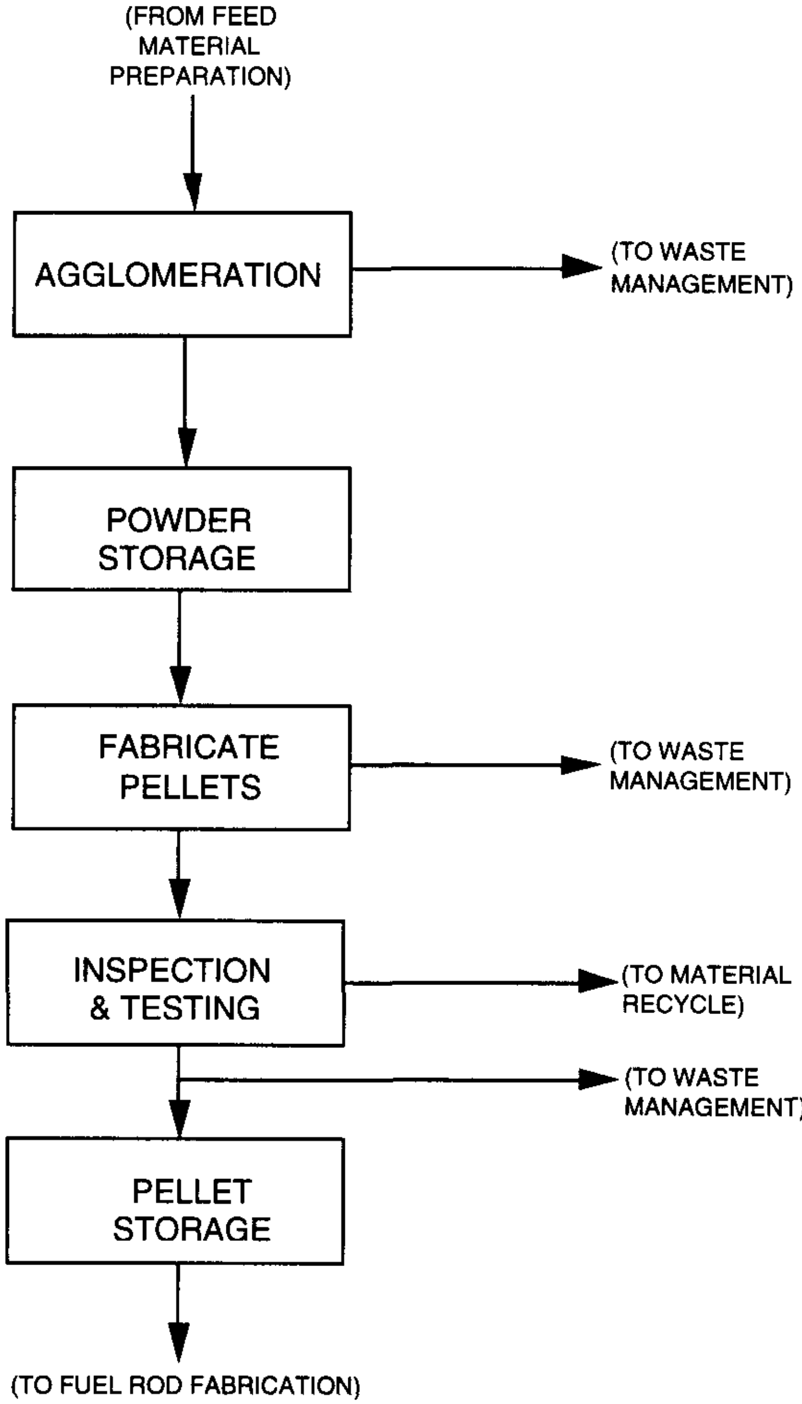


Fig. 4-5. Fuel pellet fabrication process flow diagram.

4.5.5. Fuel Pellet Fabrication: Chemicals Required. Chemicals required in this process, other than feed materials, are argon and hydrogen gases for the sintering furnace atmosphere, zinc stearate as a pressing lubricant, and polyethylene glycol as a powder handling agent. The pellet characterization methods, such as purity analyses and metallography (which use grinding and polishing fluids), require small amounts of certain analytical chemicals.

4.5.6. Fuel Pellet Fabrication: Special Requirements. Processing and storage must observe strict criticality controls, applicable regulatory requirements, safeguards against diversion of plutonium, controls designed to preclude any ingestion of plutonium powder, and any other applicable guidelines. ALARA requirements must be met.

4.5.7. Fuel Pellet Fabrication: Wastes Generated. Wastes generated include contaminated furnace(s); pellet presses; sintering boats; thermocouples, MOX, and additives dust from sintering furnace and grinding operations; contaminated operator clothing, gloves, wipes, and shoe covers; used ventilation filters and potentially contaminated hydraulic fluids from the presses; used grinder wheels; and sweepings from pressing operations. There may also be decomposed zinc stearate and ethylene glycol emissions from the furnace and deposits on the furnace.

4.6. MOX Fuel Rod Fabrication

4.6.1. Fuel Rod Fabrication: Function. Rod hardware is prepared for pellet loading, then stacks of pellets and components are assembled and loaded into the rods. The open end of the rod is decontaminated, and the second end cap is welded on. The rod is inspected for dimensional correctness and fissile loading, and a leak test is performed. Defective rods are recycled. Acceptable rods are cleaned and stored pending their assembly into fuel bundles. Figure 4-6 illustrates this process.

The pellet loading in fuel rods uses methodologies that are essentially the same as those used for the fabrication of enriched uranium fuel rods.

4.6.2. Fuel Rod Fabrication: Feeds. Feeds for this process include finished fuel pellets, rod hardware, helium gas to backfill the rod, and welding materials. Also, some rods may use depleted UO_2 insulator pellets on either end of the fuel column.

4.6.3. Fuel Rod Fabrication: Products. The products are finished fuel rods that are ready for assembly into fuel bundles.

4.6.4. Fuel Rod Fabrication: Utilities Required. Utilities used in this process include electricity for lighting, instrumentation, MC&A equipment, ventilation, handling equipment, and welding machines; and sanitary and potable water. NDT equipment is also required.

4.6.5. Fuel Rod Fabrication: Chemicals Required. Chemicals required in this process include cleaning fluids, helium gas to backfill rods and to flood the weld area on the rods, and certain analytical chemicals.

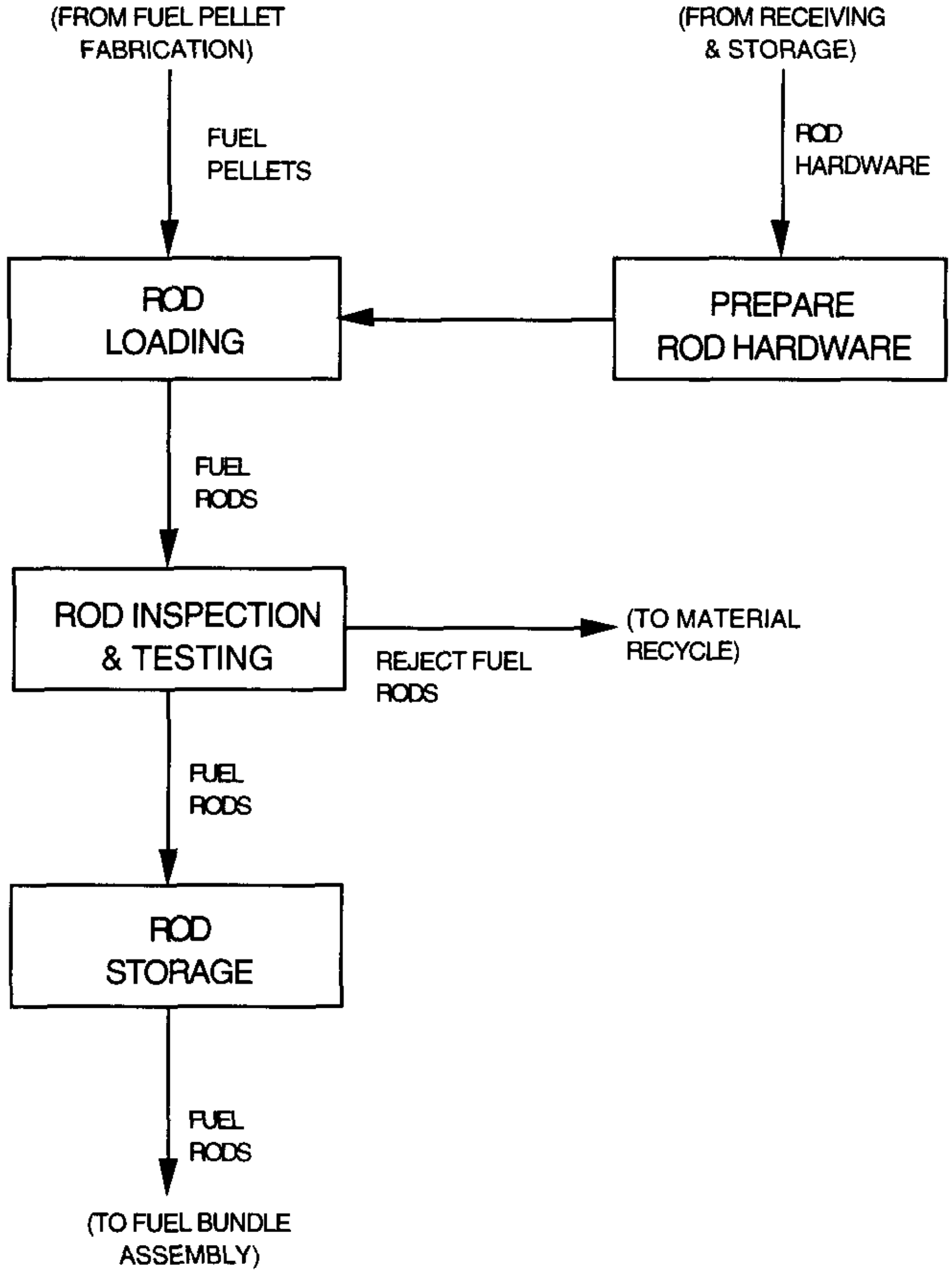


Fig. 4-6. Fuel rod fabrication process flow diagram.

4.6.6. Fuel Rod Fabrication: Special Requirements. Processing and storage must observe strict criticality controls, applicable regulatory requirements, ALARA policies, and safeguards against the diversion of plutonium.

4.6.7. Fuel Rod Fabrication: Wastes Generated. Generated wastes include materials from defective rods, contaminated operator clothing, gloves, wipes and shoe covers; sacrificial equipment such as funnels; used ventilation filters; used analytical chemicals; and cleaning solutions.

4.7. Fuel Bundle Assembly

4.7.1. Fuel Bundle Assembly: Function. Bundle components are prepared for assembly, and fuel rods are removed from storage. The bundle is assembled, cleaned, and inspected for dimensional conformance. The bundle is then stored pending transfer to a reactor. Rejected bundles are sent to the materials recycle process. Figure 4-7 shows the fuel bundle assembly process.

4.7.2. Fuel Bundle Assembly: Feeds. Feeds for this process include enriched UO_2 fuel rods, MOX fuel rods, bundle hardware, and welding materials.

4.7.3. Fuel Bundle Assembly: Products. The products are finished fuel bundles that are ready for charging into a reactor.

4.7.4. Fuel Bundle Assembly: Utilities Required. Utilities used in this process include electricity (for lighting, instrumentation, MC&A equipment, ventilation, welding, and handling equipment) and sanitary and potable water.

4.7.5. Fuel Bundle Assembly: Chemicals Required. Chemicals required in this process include cleaning fluids.

4.7.6. Fuel Bundle Assembly: Special Requirements. Processing and storage must observe strict criticality controls, applicable regulatory requirements, ALARA policies, and safeguards against diversion of plutonium.

4.7.7. Fuel Bundle Assembly: Wastes Generated. Wastes generated include materials from defective assemblies, cleaning fluids, and used ventilation filters.

4.8. Process Materials Recycle

4.8.1. Process Materials Recycle: Function. Process materials to be recycled include fuel rods and fuel bundle assemblies rejected in the final inspection and fuel pellets rejected for being out-of-specification in areas such as density, stoichiometry, homogeneity, or dimension. Rejected bundles are disassembled and the fuel rods are removed. The bundle hardware is checked for contamination, decontaminated if necessary, and disposed of as scrap. Acceptable fuel rods are placed back into storage for use in a new assembly. Rejected fuel rods are disassembled, the rod components are decontaminated and disposed of as scrap, and the fuel pellets are removed. Acceptable fuel pellets are placed back into pellet storage to be reloaded into a new fuel rod. Rejected fuel pellets are returned to the clean MOX recovery process. During fuel pellet fabrication, clean powders and sintered pellets are reused, if acceptable. The overall materials recycle process is depicted in Fig. 4-8. The process of disassembling and recycling reject fuel rods and bundles is depicted in Fig. 4-9.

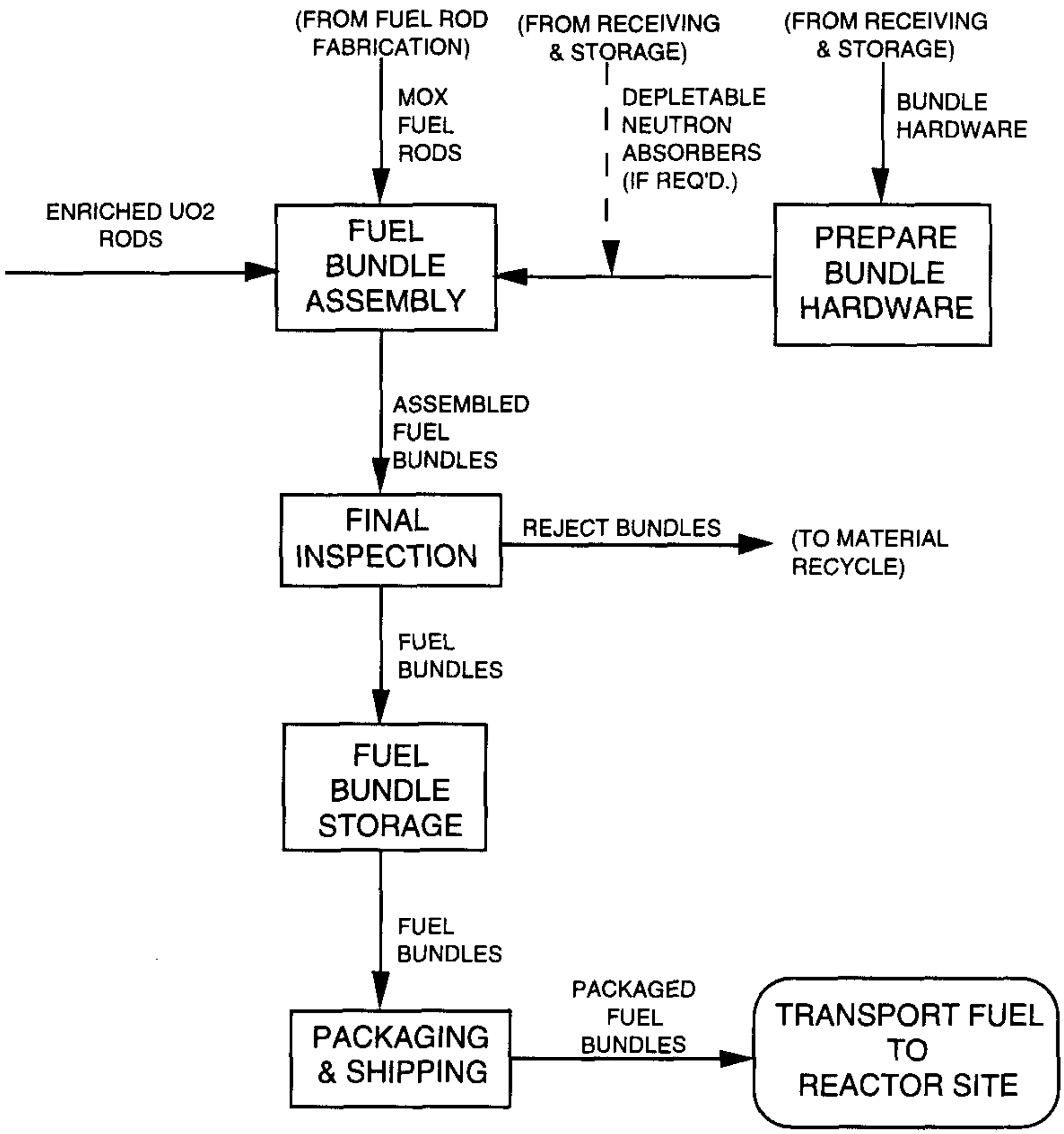


Fig. 4-7. Fuel bundle assembly process flow diagram.

Some fraction of the MOX pellets fabricated will be rejected during QA testing and inspection. In addition, excess MOX powder may be blended and MOX pellets manufactured to ensure that an adequate finished product is produced to meet contractual commitments.

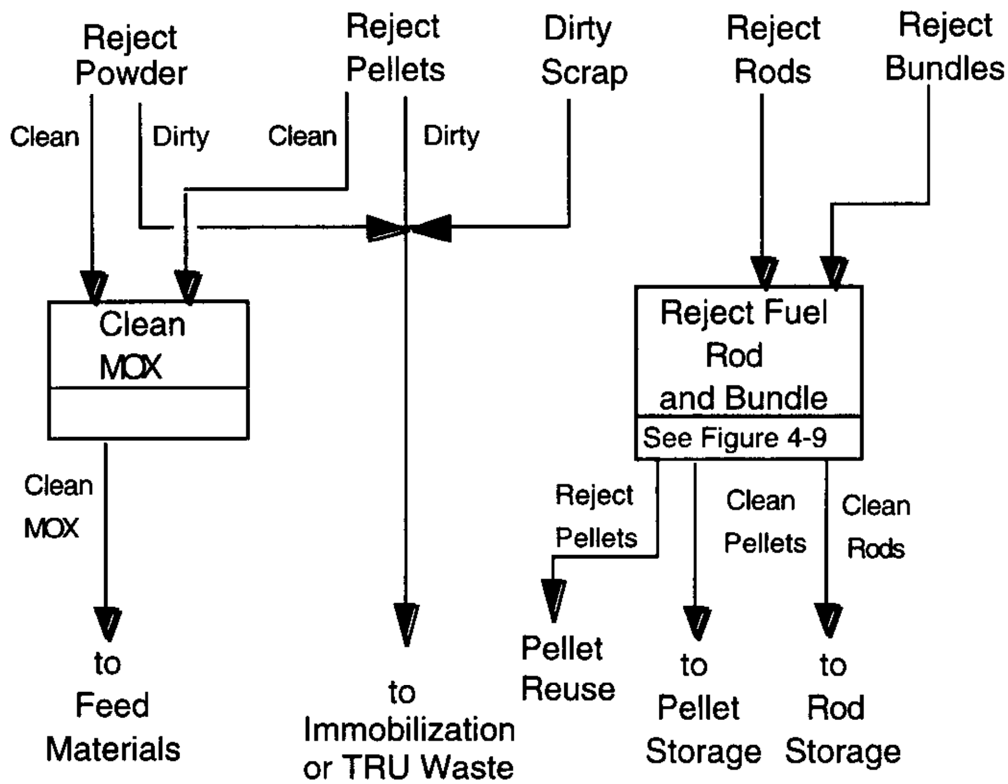


Fig. 4-8. Materials recycle process flow diagram.

Such material designated as clean scrap that does not require purification may be processed as follows: the material is (1) crushed, (2) heated in moist air to break up the crushed oxide into a powder by changing the UO_2 to U_3O_8, and (3) heated in a second furnace with an argon-hydrogen atmosphere so that the U_3O_8 reverts to UO_2. The resulting powder, after screening, is placed in MOX recycle storage and is reused to prepare fresh MOX powder. Figure 4-10 shows a flow diagram of this process. This process for converting clean scrap back into a powder suitable for refabricating into pellets has been used for many years in uranium dioxide fuel plants.

Hardware from rods that have been shipped in from other sites and disassembled in this plant would be disposed of as noted above.

PuO_2, UO_2, and MOX that have become contaminated beyond value for recycle are either packaged and disposed of as TRU waste or shipped to PCIF. Miscellaneous material, such as glovebox floor sweepings and filters containing plutonium oxide, will be packaged for shipment to on-site or off-site treatment and disposal facilities as either LLW, mixed

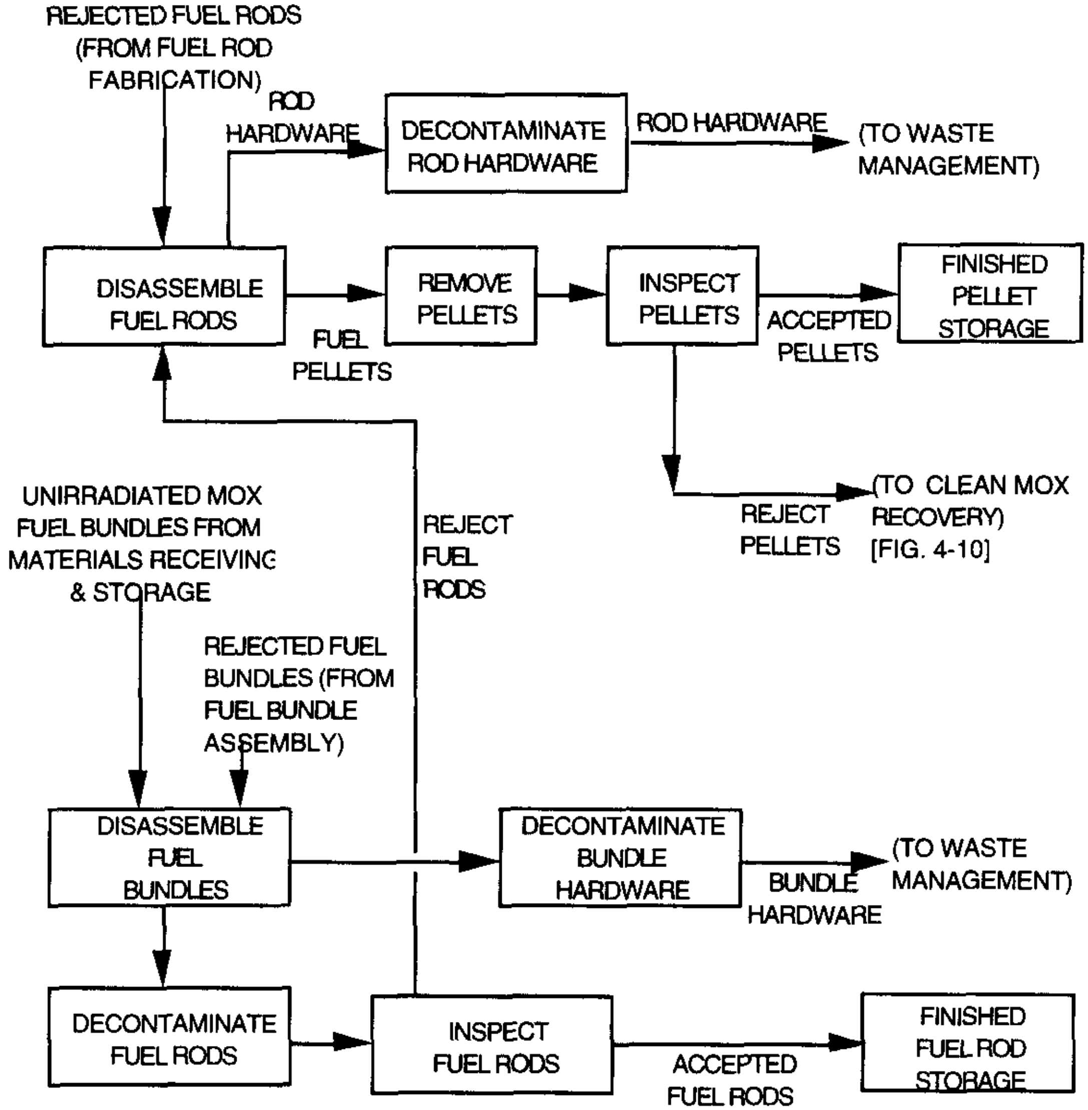


Fig. 4-9. Reject fuel rod and bundle processing flow diagram.

waste, or TRU waste. TRU waste will likely be disposed of at the Waste Isolation Pilot Plant (WIPP).

4.8.2. Process Materials Recycle: Feeds. Feeds for this process include rejected fuel rods, bundles, and pellets.

4.8.3. Process Materials Recycle: Products. The products from this process include scrap metal, new fuel pellets, reusable pellets, fuel rods, and depletable neutron absorbers.

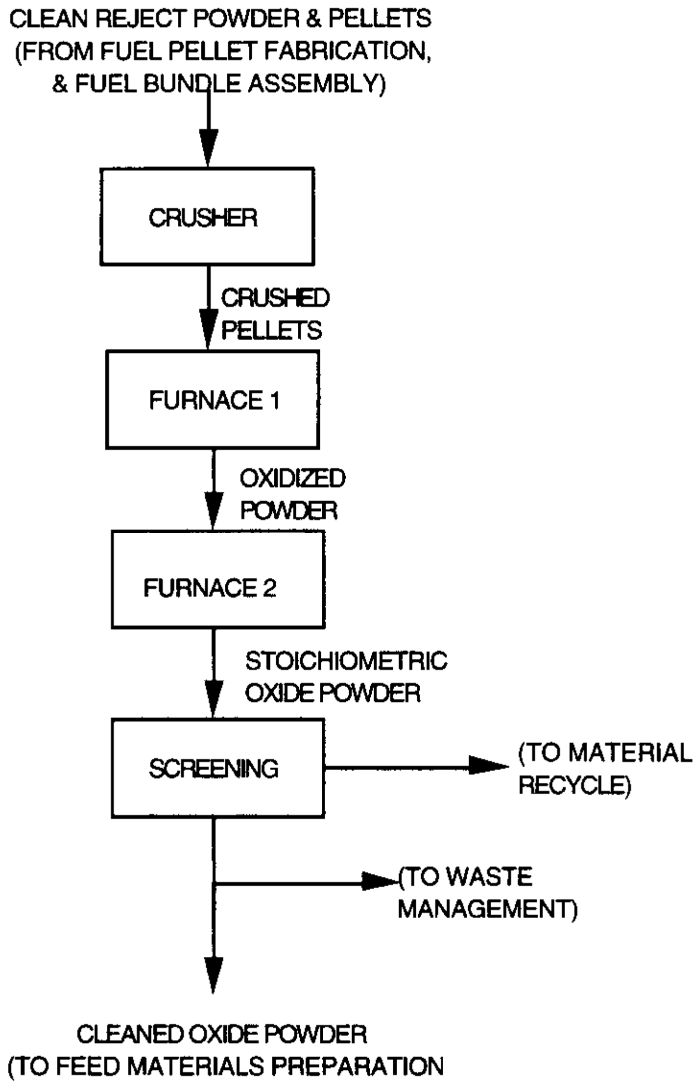


Fig. 4-10. Clean MOX recovery process flow diagram.

4.8.4. Process Materials Recycle: Utilities. Utilities used in this process include electricity for lighting, MC&A equipment, and ventilation; for powering oxidation and reduction furnaces for materials recycle, materials handling equipment, and other equipment; and sanitary and potable water.

4.8.5. Process Materials Recycle: Chemicals Required. Chemicals required in this process have been listed in the previous process steps.

4.8.6. Process Materials Recycle: Special Requirements. Care must be taken to distinguish between fuel types, poison rods, and fuel pellets. Processing and storage must observe strict criticality controls, applicable regulatory requirements, ALARA policies, and safeguards against the diversion of plutonium.

4.8.7. Process Materials Recycle: Waste Generated. Wastes generated in this process have been listed in the previous process steps.

4.9. Waste Management System

4.9.1. Waste Management System: Function. The Waste Management Process involves collecting, assaying, sorting, treating, packaging, storing, and shipping radioactive, hazardous, and mixed wastes from plutonium operations; and hazardous and nonhazardous waste from the support facilities (Figs. 4-11, 4-12, and 4-13). All wastes are packaged for shipment at existing on-site facilities, and disposed of at existing on-site or off-site facilities.

1. Initial sorting of solid waste (TRU, LLW, hazardous, mixed, etc.) is performed at the generation source. Solid wastes are treated by a variety of processes to ensure that they are in compliance with EPA, RCRA, DOT and NRC or DOE requirements, as applicable.

2. Radioactive liquid waste should be minimal. It will be stabilized and packaged appropriately at an on-site treatment facility and disposed of at an on-site or off-site facility.

3. TRU waste is packaged for shipment to a DOE-designated facility.

4. Low level mixed waste will be stabilized and packaged appropriately at an on-site treatment facility and disposed of at an on-site or off-site facility. Mixed TRU wastes are handled the same as TRU waste.

5. Nonhazardous, nonradioactive solid, aqueous, and gaseous wastes are treated in conformance with standard industrial practice. Solid wastes are disposed of either at a sanitary landfill or are sent to a commercial recycle center. Aqueous wastes are processed through the sanitary liquid waste pretreatment system, and gaseous wastes are processed through the off-gas treatment system and then released to the atmosphere.

Because MOX fuel fabrication is a dry process, there are only a few support operations yielding liquids that may be plutonium contaminated. These operations include analytical chemistry processes, process off-gas scrubbing, the use of cleaning solutions, wet decontamination operations, and miscellaneous liquid waste generating activities such as laundry, personnel showers, and rod and bundle cleaning.

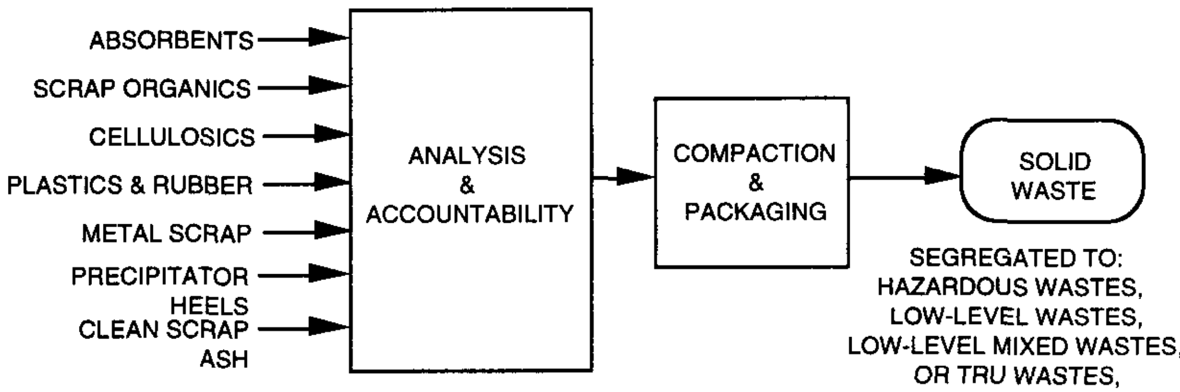


Fig. 4-11. Solid waste treatment process flow diagram.

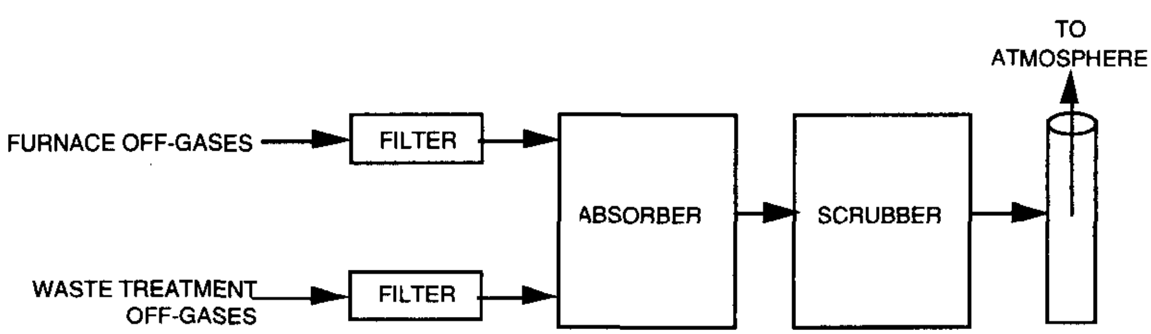


Fig. 4-12. Airborne emissions treatment process flow diagram.

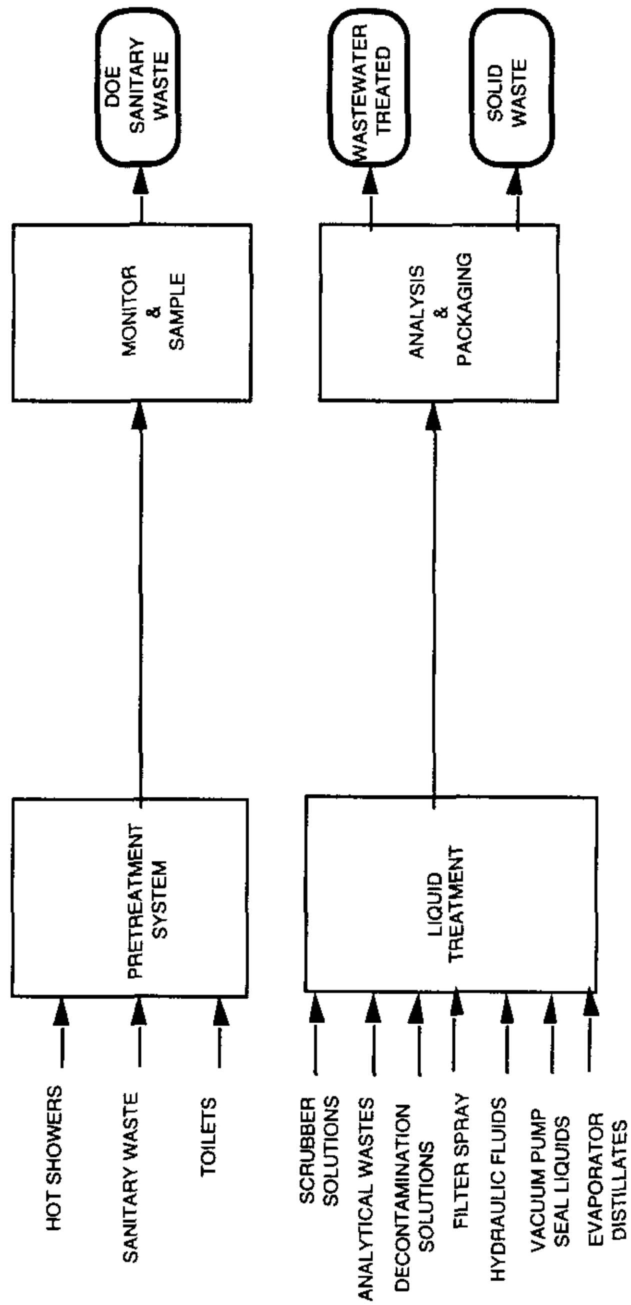


Fig. 4-13. Liquid waste treatment process flow diagram.

Treated waste water will be sampled and released from the plant if the level of radioactive material is below the limits set in 10CFR20 and the NPDES; otherwise, it is recycled for further treatment.

The solid radwaste system is designed to package residual solids like room trash, incinerator ash, and contaminated equipment for disposal in accordance with applicable regulations.

Solids such as paper, cans, and filters are compacted and packaged in drums at the fabrication plant for disposal or further treatment at a federal waste repository.

A series of redundant HEPA filters in the plant ventilation systems will remove airborne radioactive materials. The concentration of radioactive material released to the environment through the HVAC system will be in accordance with the limits presented in 10 CFR 20.

4.9.2. Waste Management System: Feeds. Feeds for this process include contaminated solids, liquid effluent, and airborne effluent, as described in the following categories.

4.9.2.1. Contaminated Waste. Contaminated wastes from the facility processes are primarily solids and liquids and are summarized in Tables 4-1 and 4-3.

4.9.2.2. Nonhazardous, Nonradioactive Wastes. Noncontaminated wastes from the facility processes are primarily solids and liquids and are summarized in Table 4-2.

4.9.3. Waste Management System: Products. Products of this process are liquid and air effluents sufficiently decontaminated to release into the environment, and solid waste suitably processed or packaged for shipment and disposal on- or off-site.

Waste management products include radioactive and nonradioactive wastes. The products are

1. Solid TRU, low-level, and mixed wastes;
2. Hazardous liquids and solids; and
3. Nonhazardous, nonradioactive solid wastes, such as compacted industrial and sanitary waste, and recyclable materials; and liquid wastes such as reclaimed water and rainwater.

The above wastes are handled and disposed of in accordance with approved storage and disposal methods. Included are the following:

1. Immobilized TRU and mixed TRU wastes sent to WIPP (may be stored on site pending WIPP operation).
2. Packaged low-level wastes and mixed wastes sent to an off-site disposal area.
3. Solid industrial/sanitary wastes sent to an off-site industrial landfill.
4. Recyclable solid wastes sent to an off-site commercial recycle center.

5. Solid and liquid hazardous wastes sent to an off-site RCRA disposal site.

6. Rain runoff discharged to natural drainage channels.

7. Nonhazardous, nonradioactive clean gases discharged to the atmosphere.

8. Sanitary waste will be pretreated and monitored before transfer to the DOE site sanitary waste system.

4.9.4. Waste Management System: Utilities. Utilities used in this process include electricity (for lighting, powering the machines for crushing dirty, rejected pellets, and powering ventilation equipment) and sanitary water.

4.9.5. Waste Management System: Chemicals Required. Chemicals required in this process may include small quantities of nitric, hydrofluoric, and oxalic acid; hydroxyl amine; and sodium nitrite.

4.9.6. Waste Management System: Special Requirements. Processing and storage must observe strict criticality controls, applicable regulatory requirements, ALARA principles and practices, and safeguards against diversion of plutonium.

Operations to handle radioactive material are carried out in gloveboxes or in other appropriate areas. Automation and robotics will be used whenever possible.

4.10. Waste Management System

4.10.1. Waste Management System: Waste Generated.

Contaminated wastes will be packaged in 55-gal drums in solidified, compacted, and/or non compacted form and will be disposed of off-site.

4.10.2. Waste Management Systems: Selected Systems for this Data Call. The preceding discussions briefly outlined the general aspects of waste treatment and disposal. At this time, a waste treatment facilities design for the new MOX FFF has not been developed. However, to determine the quantities of waste generated, a generic waste treatment approach was selected. Published European and US experience was considered.

Table 4-1. Radiologically Contaminated Waste Streams

SOLID WASTES		
Dirty scrap	HEPA filters	Other filters used in contaminated waste processing
Wipes and rags	Scrubber waste	Plutonium oxide sweepings
Spent crucibles, glassware, etc.	Failed equipment and parts	Metal drums/containers
Punch and die sets	Gloves from glove ports	Leaded glass
Retired gloveboxes	Spent resins	Cleaning sludge
Rubber	Packaging	Contaminated tools
Insulation	Glass	Plywood boxes
Batteries	Discarded protective clothing	Paper
Plastics	Heating elements	Insulation
Gloves	Metallographic lab mounts, grinding and polishing waste	Absorption bed cartridges
LIQUID WASTES		
Laboratory waste	Cleaning solutions	Spent lubricants
Vacuum pump oil	Laundry waste water	Spent scrubber solutions
Hydraulic fluids	Film developing chemicals	Contaminated fire water
Lavatory wastes	Paints	Organic liquids

Table 4-2. Non-Radiologically Contaminated Waste Streams		
SOLIDS		
Clean, non-plutonium metal	Industrial wastes from utility and maintenance operation	Office and cafeteria wastes
Broken equipment, tools	Solids from secondary side blowdown	Scrap tubing, assembly hardware
LIQUIDS		
Sanitary water	Blowdown water	Rain water
Machine shop cuttings and grinding fluids	Process cooling water	Pump oils
Hydraulic fluids	Solvents	

4.10.2.1. European Experience. Waste treatment processes are designed to deal with the process waste created by a MOX plant. These processes must address waste generation, treatment, and disposal. European MOX fuel technology is generally viewed as the most current fabrication technology experience available today. Although certain aspects of European MOX technology differ from the proposed MOX FFF, the European waste treatment experience can be used to extrapolate expected waste volumes for the MOX FFF.

The approaches to waste treatment in Europe and the US are not expected to differ significantly. For example, the waste categories for US waste treatment, defined in section 7, differ somewhat from those used in France. For the MELOX plant in France, scrap plutonium is either recycled directly (clean scrap) or chemically treated and then recycled (dirty scrap). So-called "technological wastes" are divided into organic and metallic wastes. Organic wastes are burned (or compacted), and the ashes from the incinerator are chemically treated at La Hague plant to recover plutonium. Metallic wastes are decontaminated by chemical and mechanical processes and packaged.

Details on waste treatment processes involved and material balances are not available in the open literature. For illustration purposes only, and mainly to support the conclusion that European waste estimates cannot be directly applied to a US MOX FFF, the following information is presented, taken from an article in Nuclear Technology from April 1994 by D. Haas et al. (Ref. 4-3).

Based on experience with the CFC and Belgonucleaire plants, for the 120-MT MELOX plant, the annual wastes have been estimated to be

50 tons of contaminated burnable wastes
30 tons of clean plastic wastes.

Table 4-3. Powder-to-Assembly Waste Streams		
Process Step	**Waste Stream**	**Recovery Status**
Powder processing	Rejected clean MOX powder lots	FR
	Rejected dirty MOX powder lots	PR
	Process room HEPA filters	PR
	Glovebox cleanup system filters	PR
Pellet processing	Sintering furnace off-gas (hydrogen, argon, water vapor, carbon dioxide, residual lubricant)	NA
	Rejected sintered pellets	FR
	Grinder sludge and pellet chips	FR
	Grinder coolant filter	PR
	Sludge dryer vent air	NA
	Pellet dryer vent air	NA
	Grinder sump liquid waste	PR
	Grinding wheels	NR
	Process line HEPA filters	PR
	Process room HEPA filters	PR
Closed loop system, occasional coolant replacement	Glovebox cleanup system filters	PR
	Sintering furnace coolant	NA
Fuel rod assembly	Scrap fuel rod hardware (SS)	NR
	Decontamination wipes	PR
	X-ray photo processing material	NA
	Process line HEPA filters	PR
	Process room HEPA filters	PR
	Glovebox cleanup system filters	PR
	Pellet drying furnace vent air	NA

Table 4-3. Powder-to-Assembly Waste Streams (cont.)

Process Step	Waste Stream	Recovery Status
Fuel assembly fabrication	Cleaning wipes	NA
	Cleaning solution	NA
	Rinse water	NA
	Process line HEPA filters	NA
	Dryer vent air	NA
	Process room HEPA filters	NA
Analytical services	Scrap powder	FR
	Scrap pellets	FR
	Sulfuric acid	PR
	Nitric acid	PR
	Rinse water solutions	PR
	Cleaning solutions	NA
	Epoxy resins	PR
	Miscellaneous analytical chemicals	NR
	Miscellaneous liquid waste	PR
	Miscellaneous solid waste	PR
	Lab scrubber solutions	NA
Clean scrap recovery	Scrap furnace off-gas	NA
	Process line HEPA filters	PR
	Process room HEPA filters	PR
	Glovebox cleanup system filters	PR

Table 4-3. Powder-to-Assembly Waste Streams (cont.)

Process Step	Waste Stream	Recovery Status
Miscellaneous waste treatment	Clean MOX scrap	FR
	Dirty MOX scrap	shipped off-site
	Sintering furnace off-gas	NA
	Oxidation furnace off-gas	NA
	Processed solid waste	NR
	Contaminated wastewater	NR
	Scrubber solutions	NA
	Process line HEPA filters	PR
	Process room HEPA filters	PR
	Glovebox cleanup system filters	PR
Liquid waste treatment	Water condensate	NA
	Drummed concreted sludge	NR
	Spent filters	PR
	Process line HEPA filters	NA
	Process room HEPA filters	NA
Effluent waste treatment	Ion exchange resins	NR
	Spent filters	PR
	Clean wastewater	NA
	Contaminated wastewater	NR
	Process Line HEPA filters	PR
	Process room HEPA filters	PR
	Glovebox cleanup system filters	PR

FR full recovery of waste fuel material
PR partial recovery of waste fuel material
NR non-recoverable quantities of fuel material
NA fuel material not expected in waste stream

On a volume basis, the estimated quantities of waste for the 120-MT MELOX plant have been estimated to be

	Burnable	Suspect
waste (liter/kg Pu)	28	17
waste (liter/kg HM)	2.3	1.4

According to Haas, it is expected that automation at the MELOX plant should reduce these waste quantities.

Applying those correlations, without any adjustments, to a US MOX FFF with a dirty scrap loss of less than 500 kg of heavy metal annually would yield a waste volume of less than 2,000 l or about ten 55-gal. drums annually, which is well below any waste estimates for US MOX plants without dirty scrap recycle. There is no information available in the open literature that would provide a basis for such required adjustments. Therefore, no use is made of these European data.

4.10.2.2. US Databases on MOX Fuel Waste Treatment. Because the waste treatment processes and the waste generation in a US MOX FFF will depend on the actual design of such a facility, use is made of former US designs for which information, albeit limited, is available.

The MOX FFF operational waste data provided below are based on particular handling and processing of waste streams described in the 1993 Westinghouse Environmental Report prepared for the NRC (Ref. 4-4), supplemented by information contained in the Westinghouse Pu Disposition Study (PDS) of 1994 (Ref. 4-5), a PNL study published in 1979 (Ref. 4-6), NRC's GESMO report (Ref. 4-7) and NRC nuclear fuel cycle risk assessment published in 1982 (Ref. 4-8).

There are three forms of contaminated or potentially contaminated waste that will leave the MOX FFF. These include process and suspect liquids, miscellaneous solid waste, and process gases and air that will be filtered. Each waste form will be treated differently. All waste streams will be controlled, monitored, and treated before discharge to minimize any adverse effects on the environment and ensure compliance with state and federal requirements.

There are four systems that control airborne, liquid, and solid waste, namely

1. the heating, ventilation and air conditioning (HVAC) system,
2. the liquid effluent treatment (LET) system,
3. the liquid waste treatment (LWT) system, and
4. the miscellaneous waste treatment (MWT) system.

The HVAC system must establish air flow patterns to prevent the spread of contamination in the event of off-normal operating/accident conditions and to maintain differential pressures between the clean areas and areas of potential contamination. The HVAC system has to perform two major functions, namely (1) to remove by a series of HEPA filters the airborne particulates so that the quantity of airborne plutonium contaminant released from the MOX FFF will be as low as practicable and not exceed regulatory limits; and (2) to protect plant and site personnel from particulate dispersions to a level as low as practical.

The function of the LET system will be to collect, monitor, and treat, as necessary all potentially contaminated aqueous effluents from the MOX building, and ensure that only those effluents that contain activity levels within the regulatory limits are released from the plant.

The amount of liquid effluents to be processed will be approximately 200 gal./day.

The function of the LWT system will be to receive contaminated aqueous waste material from the LET and MWT systems, convert it into a solid form, and package it for off-site disposal. The amount of liquid waste to be processed will be approximately 10 gal./day. All contaminated liquids will be discharged as solidified waste. The total number of sealed drums for off-site disposal will be expected to average 40 drums per year.

The function of the MWT system will be to accept all wastes not piped to liquid systems from all areas of the building and to prepare them for disposition. The material will be treated for the recovery of plutonium when feasible or for disposal as solid disposable waste. It is estimated that 175 drums of non compacted waste and 200 drums of compacted waste will be prepared for disposal annually.

The LWT system and MWT system both receive input from the LET system. Any solid waste produced in the LWT system will be sent to the MWT system for treatment and disposal. Any aqueous waste produced in the MWT system will be sent to the LWT system for treatment and disposal.

In addition to these waste treatment systems that mainly deal with contaminated waste, there is a sanitary waste treatment system. The sources of waste going to the sanitary system are conventional plant waste streams (lavatories, showers, toilets), the cooling tower blowdown, and the LET waste system. The discharge from the LET waste system contains traces of chemicals from laboratory sinks, process chemical makeup, and floor mopping. By diverting this stream into the sanitary waste treatment system, additional benefits will be derived by breaking down biodegradable floor mopping detergents and corrosion inhibitors (orthophosphates) from the cooling tower blowdown. Treated sanitary water will leave the plant for ultimate disposal (e.g., into creeks, rivers, etc.).

More detailed descriptions of the different waste treatment systems follow to explain the basis for the waste amounts cited in section 7.2.1.2.

Liquid Effluent Treatment (LET) System

Liquids generated or used in the manufacturing building that do not have direct contact with the manufacturing process are expected to be free of plutonium contamination. However, because they are present in the manufacturing building, it is possible that at times these liquids will become contaminated.

The LET system receives, monitors, and processes all such liquid plant effluents, as necessary, before release to the sanitary waste treatment system. These effluents are commonly referred to as "potentially" contaminated. They include effluents generated from janitorial activities (mop water), personal decontamination, the hood and glovebox off-gas fume scrubbers, cold analytical laboratory sinks, and dehumidification condensate from ventilation equipment. Note: The LET system does not process discharged sanitary water (sinks, toilets, showers, cafeteria); this water is discharged directly into the sanitary waste treatment system.

The effluents going to the LET system are drained to retention tanks where they are mixed to achieve homogeneity, monitored, pH adjusted if required, filtered, and analyzed for radioactive contamination. If the contamination level exceeds the discharge limit (e.g., 10 CFR 20), the effluent will either be decontaminated to permissible discharge limits or transferred to the LWT system for solidification in drums. The deactivation treatment in the 1994 Westinghouse MOX fuel fabrication plant was accomplished by passing the contaminated solution through a series of filters plus ion exchange columns and an absorption column for removal of both particulate and dissolved radioactive contaminants.

Because of the potential for mop water to contain significant quantities of miscellaneous dirt and other particulate matter, it is initially collected in separate holding tanks. Particulate matter will either be removed as sediments or contained in filters.

The laundry for operating personnel clothing is located within the MOX complex but outside the fuel fabrication facility. All laundry effluent will be monitored before discharge. If found to be contaminated, laundry effluent will be directed to the LET facility for processing.

The output from the LET system goes to the following systems:

Sanitary waste treatment system:	All liquids that have been neutralized and have activities below the allowable discharge limit
Liquid waste treatment system:	Liquids that even after several deactivation cycles in the LET system still show activities above the allowable discharge limit

Miscellaneous waste treatment system:	Spent filters, demineralization cartridges, other cartridges

Liquid Waste Treatment (LWT) System

The purpose of the LWT system is to receive, process for volume reduction, and package for disposal aqueous liquid wastes containing nonrecoverable quantities of fissile material or radioactive waste contaminants in excess of permissible levels.

The facility receives aqueous liquid waste effluents only from the other waste process systems, namely the LET and MWT systems. These wastes have previously been (a) processed already for removal of fissile material to the degree feasible and (b) characterized with respect to residual fissile content and radioactive content.

In the LWT process, liquid wastes are collected in an evaporator feed tank for mixing to obtain a homogeneous liquid and characterization. This liquid is then metered to an evaporator for volume reduction. The moisture from the evaporation process is condensed, collected, and monitored before release to the plant drain system. If monitoring should detect radioactive carry-over, the collected condensate can be recycled back to the LWT system.

The concentrate from the evaporator is sent to solidification feed tanks to accumulate the waste concentrates and provide for (a) mixing for homogeneity, (b) filtering of any particulate matter remaining in the liquid, and (c) sampling for the determination of fissile content.

From the solidification feed tank, the waste liquid is directed to a solidification head tank, where the liquid waste is discharged into a concrete mixer and mixed with a measured quantity of concrete. The mixed concrete batch is then discharged into lined 55-gal. (208 L) drums for curing. The plastic liner is then sealed, followed by the sealing of the drum lid.

The outsides of the sealed drums are scanned and, if necessary, decontaminated before they are stored for disposal.

Westinghouse (Ref. 4-4) estimated that for a production plant capacity of 150 MT/yr, approximately 40 drums/yr would be disposed of, of which 36 concreted drums would contain TRU waste and 4 concreted drums would contain mixed TRU waste.

Spent filters from the LWT system will be sent to the MWT system.

The condensed moisture from the evaporators will be sent to the plant drain system. The overall water balance and the amount of water sent every day to the sanitary water treatment system, is measured in the tens of thousands of gallons; the water from the

LWT system sent to the sanitary water treatment system is measured in gallons per day.

Miscellaneous Waste Treatment (MWT) System

The MWT system processes a wide variety of wastes generated in the manufacturing building that differ in plutonium content and/or physical description. All wastes excluded from the LWT and LET systems will be sent to the MWT system.

The MWT system receives, sorts, processes, and packages all these materials for either off-site disposal or in-plant storage. Wastes processed include all solid wastes, organic wastes, and certain analytical lab wastes, as well as some hardware and small process equipment that have had contact with fuel materials and are to be repaired or scrapped.

Westinghouse (Ref. 4-4) had estimated that for a 150-MT/yr MOX FFF over 8,000 ft^3 (227 m^3) of miscellaneous waste material will be generated every year. This estimate includes some allowance for the disposal of empty plutonium oxide shipping containers. The key objective for the MWT system is to reduce the quantity of fissile wastes to be disposed of. Recoverable (clean scrap) plutonium will be separated physically from other materials packages as much as possible and will be collected in sealed containers.

Another type of waste is identified as dirty scrap. This is mixed oxide fuel that has become mixed with non-fuel material and, therefore, cannot be recycled as clean scrap. Materials falling into this category are

1. contaminated MO_2 and PuO_2 powder, MO_2 pellets, chips
2. sweepings
3. analytical and quality control samples
4. liquid wastes from the analytical lab
5. filter elements from LWT and LET systems

All these wastes will be characterized and separated into recoverable and nonrecoverable categories.

The objectives for the MWT system are the packaging of dirty scrap fuel for off-site disposal at a DOE site and volume reduction and packaging for disposal of waste materials contaminated with low, nonrecoverable levels of TRU waste.

Some of the kinds of materials that will make up this volume of waste are

1. wipe rags and paper
2. gloves from glove ports
3. plastic bags, bottles, tubing, sheet materials

4. metallographic lab mounts, grinding and polishing waste
5. filter elements
6. absorption bed cartridges
7. surgeon gloves
8. blotter paper
9. discarded protective clothing
10. solvents
11. spent lubricants
12. wastebasket paper
13. scrap hardware, tools, and equipment
14. certain analytical services facility solid wastes such as scrap tubing, glassware, and crucibles.

The amount of plutonium attached to these materials varies from zero to recoverable amounts. Nonfunctional large equipment items are not processed by this system but would be disposed of through the equipment decontamination and maintenance repair areas.

The MWT system consists of gloveboxes with specialized functions that are interconnected with a conveyor system. Materials enter the MWT system from the various FFF waste generation areas and are transferred by an enclosed conveyor to the transfer operations glovebox. This box serves as a common distribution area for all waste/scrap materials that are to be processed by the MWT system. All materials are segregated in this box according to fissile content and physical characteristics. Wastes containing no or negligible nonrecoverable quantities of fissile material are transferred to drum disposal. Wastes containing recoverable quantities of fissile material are transferred to the appropriate waste treatment operations box. Examples of such boxes are the shred/wash precipitate filter/dry box, mechanical/special treatment box, mechanical separation box, organic treatment box, roasting box, gamma scan/neutron scan box, drum disposal compaction or noncompaction box, and a weigh/blend/package box.

Waste containing significant quantities of scrap MOX products, such as process filters, vacuum bags, are sent to the mechanical separation box, where dry mechanical cleaning methods are employed to remove dry MOX powder from those items.

Combustible solids with measurable quantities of fissile material are forwarded to the roasting operations where they are roasted and ashed. Precipitate filter cakes from MWT processing are also processed in this box. The materials are then placed in the furnace in containers.

Waste organic compounds and solutions generated or used in the FFF, such as oils, lubricants, greases, and solvents, are transferred to the mechanical treatment box. They are sent to the roasting box after particulate matter has been removed through the use of filters.

Plastic materials, rubber gloves, disposable filters, etc., with recoverable quantities of fissile material are processed in the shred-wash-precipitate-filter-and-dry box.

Analytical lab solutions resulting from fuels analyses and testing that contain recoverable quantities of fissile material are processed in the precipitation-and-filtration box. These normally acid solutions are treated to neutralize them and to precipitate out solid fissile materials. The residual solution is transferred to the LWT operations for concentration, solidification, and packaging for disposal.

All waste processed by the MWT system is surveyed prior to drumming for disposal or for transfer to additional waste treatment steps.

Sanitary Waste Treatment System

The sources of waste to the sanitary system (a modern sewage treatment plant) will be conventional plant waste streams (lavatories, showers, toilets), the cooling tower blowdown, and the LET waste system. The discharge from the LET system will contain traces of chemicals from laboratory sinks, process chemical makeup, and floor mopping.

The main requirements for the sewage treatment plant will be the removal of organics, the reduction of the biochemical oxygen demand discharge level, and reduction and the retention of suspended solids.

Treated sanitary water will leave the plant for ultimate disposal (by river, creek, spray field, etc.).

4.11. References

4-1. Storage and Disposition of Weapons-Usable Fissile Materials Final Programmatic Environmental Impact Statement - Summary, DOE/EIS-0229, p. S-23.

4-2. (Private communication with Vickie White at Oak Ridge National Laboratory, 16 July 1997).

4-3. D. Haas et al., "Mixed-Oxide Fuel Fabrication Technology and Experience at the Belgonucleaire and CFCa Plants and Further Development for the MELOX Plant."

4-4. Environmental Report, Westinghouse Recycle Fuel Plant, prepared by Westinghouse for the NRC, July 1973, Docket Number 70-14323.

4-5. Westinghouse Pu Disposition Study (PDS), August 1994 .

4-6. "Description of Reference LWR Facilities for Analysis of Nuclear Fuel Cycles," PNL-2286, September 1979

4-7. "Final Generic Environmental Impact Statement on the Use of Recycle Plutonium in Mixed Oxide Fuel in Light Water Cooled Reactors," NUREG-0002, Vol. 3, August 1976.

4-8. "Nuclear Fuel Cycle Risk Assessment, Description of Representative Non-Reactor Facilities," NUREG/CR-2873, Vol. 1, September 1982.

5. RESOURCE NEEDS AT THE SRS SITE

5.1. Construction Resource Needs

None of the existing buildings at the SRS site meet the building screening criteria that had been established for the site feasibility assessment conducted during 1996 (Ref. 5-1). A MOX FFF at SRS would be a newly constructed facility.

A three-year construction schedule was assumed for building the MOX FFF. The number of construction workers for years 1 through 3 is estimated to be 200, 350, and 230, respectively, with a total construction effort of 780 worker-years (see section 6).

Commonly, the startup period is considered part of the construction period even though the on-site activities differ greatly during construction and startup. For this data call report, a one-year cold startup involving 300 workers is assumed, followed by a one-year hot startup with 400 workers. During the initial cold startup activities, some minor construction work, as well as quality assurance activities, needs to be completed, and as those construction activities decline, operating staff is built up. During the hot startup period, the operating staff is gradually built up to the level required for normal operation. To bound this staff level, 400 workers were assumed to be involved throughout the hot startup of the MOX FFF.

5.1.1. Utility Needs during Construction. The data call report for the accelerator production of tritium (APT) project (Ref. 5-2) was used to derive certain correlations for utility needs during construction as described below.

<u>Electricity use</u>: The basis for electricity use is the following: it is assumed that dewatering at a construction site for a new plant consumes as much electricity as other uses except at desert sites. During construction it is assumed that the only electrical loads are for temporary construction power (dewatering, lights, electric hand tools, etc.) and that the total annual consumption would be approximately 750 MWh. It is also assumed that if dewatering was required, it would consume as much energy as the construction related activities. This would allocate 750 Mwh for dewatering and 750 MWh annually for other construction uses. The maximum dewatering capability will be required only during the first year of construction until some water containment (completion of the building basement/foundation) or in-leakage barrier technique is employed. Because the SRS site is a semidry site, it was assumed only half the amount of electricity allocated for dewatering was used (0.5 x 750MWh/yr = 375 MWh/yr) in the first year. The total estimated electricity use over 3 yr is therefore 3 x 750 + 375 Mwh or 2,625 Mwh. This values equates to an average consumption of ~73 Mwh/month or an hourly average of about 101 kwh. A peak can be estimated at 1.5 times this value or ~151 kw_{peak}.

Electricity consumption during the cold startup is expected to be low, whereas electricity consumption during the end of the hot startup will be close to that required for normal plant operation (i.e., approximately 1,000 MWh per month). Thus, the cold startup year is expected to be about half the value of normal operations or 6000 Mwh/yr (0.5 x 12,000 Mwh/yr). The hot startup year is expected to be similar to normal operations or 12,000 Mwh/yr. The total is therefore 18,000 Mwh for the two startup years. This equates to an hourly average of 1,041 kw/hr or a peak of 1.5 x 1,041 kw = 1,562 kw_{peak}.

Fuel use: for a new MOX FFF is assumed (a) a rolling 4 - 10 h/day or 5 - 8 h/day construction schedule; (b) four pieces of construction equipment, each fitted with a 550 hp diesel which consumes an average of 10 gal./hr for 12 months; and (c) one crane consuming 5 gal./h over the following 12 months. An additional 10% was included to account for use by vehicles, portable generators, and contingencies.

Over the three year construction period the fuel use was estimated to 684,000 L (180,750 gal.) or an average annual consumption of 228,000 L (60,200 gal.).

Water use: The dominant uses of water during construction are for the satisfaction of personal needs and, to a lesser extent, for concrete mixing. It has been estimated that for each m^3 of concrete, 0.17 m^3 water is consumed. For the construction of a new MOX FFF at SRS, the use of 12,060 yd^3 (9,216 m^3) of concrete was estimated. This implies 405,000 gal. (1,570,000 L) of water for concrete. Water consumption during construction is estimated at 1 gal./day for construction workers assuming water is primarily provided for drinking and that portable sanitation facilities are provided. The personnel water requirements, based on the construction personnel provided in section 6 and 256 work days/yr, are

Year	Personnel	Water (gal.)
1	256 days x 200 workers x 1 gal./day per worker =	51,200
2	256 days x 350 workers x 1 gal./day per worker =	89,600
3	256 days x 230 workers x 1 gal./day per worker =	58,880
	concrete (see above)	405,000
	Total	604,680
	50% contingency (see text)	302,340
	Total consumption	907,020

The nominal water consumption during construction (personal use, use for concrete, etc.) was increased by 50% to address other construction uses (dust control, cleaning, etc.). During startup the annual water consumption will increase. The average annual water consumption is assumed to be 10 gal./day during cold startup and 25 gal./day during hot startup (Ref. 5-6). During hot startup all of the process requirements are assumed to be required as shown in section 5.2. The startup requirements are therefore

Year	Personnel	Water (gal.)
cold	256 days x 300 workers x 10 gal./day per worker =	768,000
hot	256 days x 400 workers x 25 gal./day per worker =	2,560,000
	Process (see section 5.2, 187+22680+8 gal./day x 365)	8,349,375
	Total	11,677,375

The total water use during the five year construction and startup period is therefore estimated to be 47,615,300 L (or ~12,580,000 gal.). Peak demand would occur during the fifth year (hot startup) and would be 10,849,000 gal. (41,064,000 L). This results in an average consumption of 2,516,000 gal./yr (9,523,000 L/yr). It is assumed that the water is drawn from the DOE site potable water system which is supplied by local wells (ground water). It is also assumed that the concrete is supplied from a local batch plant which also uses ground water (wells) for the preparation of concrete. The utility use during construction is shown in Table 5-1.

5.1.2. Chemicals. The large-scale use of liquid chemicals during construction is generally limited to the chemical flush of cooling systems. For the very large APT cooling systems, this is done using tanker trucks carrying three 18.9 m^3 (5,000 gal.) tanks, one each for Na_3PO_4, phosphoric acid, and demineralized water. These chemicals are generally recycled and filtered. It was assumed for the APT data call Report that the contents of such trucks were depleted each month during a six-month system-commissioning period, leading to a total use of 250 m^3 of chemicals.

It is assumed that for the much smaller cooling system for the MOX FFF (removal of a few hundred megawatts for the APT compared to only a few megawatts for the MOX FFF) only 5 m^3 each of Na_3PO_4, phosphoric acid, and demineralized water are used.

The use of chemicals is shown in Table 5-1.

5.1.3. Building Materials. The volume of concrete required for the construction of a new MOX FFF was estimated to 12,054 yd^3 (9216 m^3) based upon preliminary layout sketches developed from available design information and interface requirements.

The estimated quantities of carbon steel required for construction include the amounts needed for reinforcing steel, structural steel, and steel siding. It was assumed that the steel volume is 4% of the concrete volume, or 3,611 tons.

In addition to the structural steel, carbon and stainless steel are being used for piping and duct work, and small quantities of wire and paint are also being used. Lumber is used for framing during construction.

The amount of building materials used for the construction of a new MOX FFF are shown in Table 5-1.

5.1.4. Radioactive Materials. No radioactive materials are used during construction.

TABLE 5-1. SRS: RESOURCE NEEDS FOR CONSTRUCTION OF A NEW MOX FFF	
RESOURCE REQUIREMENTS	**AVERAGE ANNUAL CONSUMPTION**
UTILITIES	
Electricity, Mwh	1125 Mwh/yr for 3 year construction
Peak demand, Mwh[a]	9,000 Mwh/yr during 2 yr startup, total of 20,250 Mwh over a 5 year period 151 kw during construction 1,562 kw peak during startup
Fuel, L (gal)	228,000 L (60,200 gal.) [684,000 L (180,750 gal.) over 3 years]
Water, L (gal.)	
Ground, average consumption, L/yr (gal./yr)	9,523,000 L/yr (2,516,000 gal./yr)
Peak Demand, L (gal.) (5th year)	41,064,000 L (10,849,000 gal.)
Total 5-year consumption	47,615,300 L (12,580,000 gal.)
Surface Water, L (gal.)	0
CHEMICALS	
Gases, m^3 (scf)[b]	
oxygen	1,387 m^3 (49,000 scf)
acetylene	368 m^3 (13,000 scf)
argon	500 m^3 (17,600 scf)
nitrogen	700 m^3 (28,571 scf)
Liquids, L (gal.)	
phosphoric acid	5,000 L (1,320 gal.) [total over 3 yr]
demineralized water	5,000 L (1,320 gal.) [total over 3 yr]
muriatic acid (dilute 10% by volume)	4,376 L (1,156 gal.) [total over 3 yr]
Solids, kg (lb)	5 m^3 [total over 3 yr]
Na_3PO_4	20 tons
dust control saw dust	
BUILDING MATERIALS (total usage during the 3-yr construction period)	
Concrete	9,216 m^3 (12,054 yd^3)
Structural steel	3,611 tons (7,965,000 lb)
Paint	10,785 L (2,850 gal.)
Wire	9 tons (20,000 lb)
Lumber	2,000 m^3 (56,600 ft^3)
Piping steel	45 tons (100,000 lb)
Piping stainless steel	22 tons (50,000 lb)
Cladding steel (for fabrication room walls)	55 m^3 (431 MT)
RADIOACTIVE MATERIALS	
none	

Notes:

a. The peak demand is the maximum rate during any hour.

b. Standard cubic feet for gases is measured at 14.7 psia and 60° F.

5.2. Operational Resource Needs

In the absence of a new MOX FFF design and its operational analysis, the resource needs during operation listed in Table 5.2 are based on an evaluation of descriptions in the public domain of past US MOX FFFs. Among those, the "Environmental Report, Westinghouse Recycle Fuels Plant" of 1973, referred to as ER-W (Ref. 3), which was prepared for the NRC, was found to be particularly valuable because of its comprehensive and coherent description of such a plant.

Note: Although the open literature publications describing US MOX fuel fabrication plants are based on a 1973 Westinghouse MOX plant design, the individual plants described in those reports differ in a variety of ways (throughput, linkage to other fuel cycle facilities, dirty scrap recycle, waste treatment, staffing, etc.). The use of any of the published data had to be carefully evaluated to ensure consistency with the new MOX FFF under consideration today.

It is assumed that the MOX FFF always operates at the design throughput capacity. While the actual operation of the MOX FFF might be linked to the fuel demand that is low initially and higher in the later phases of the disposition mission, using performance data related to the as-designed fabrication capacity of the MOX FFF is expected to bound the data requested in the data call.

5.2.1. Utilities

Electricity use: Based on the adjustments to ER-W (Ref. 5-3) data and a comparison with other early US MOX plant operation and design descriptions, an annual electricity use of 12,000 MWh for a 100-MT MOX FFF was assumed. This equates to an average consumption of 1,388 kw/h and a peak consumption of 1.5 x 1,388 kw = 2,083 kw. The 1.5 value is a typical "rule of thumb" value for a peak when the average is known for an industrial type facility.

Coal: It is assumed that the MOX FFF will be heated with process steam generated by a coal-fired boiler at SRS. The incremental coal usage is approximately 29.22 lb coal/ft^2 per year, or 3.51×10^6 lb (1,750 tons, 1,590 MT) coal per yr for a 114,000-ft^2 building.

Basis:
32,500,000 scf natural gas/yr at Pantex for generic facility (Ref. 5-4, Pantex Data Call Report, LA-UR-97-2067)

2,497 degree days (DD) at SRS
4,037 DD at PANTEX

Coal required at SRS:
{(32,500,000 scf)(1,050 BTU/scf)/(14,000 BTU-lb coal)}(2,497 DD/4,037 DD)
(114,000/120,000) = 1.43×10^6 lb coal (650 MT)

Natural Gas: None

Oil: The principal uses of motor fuel during operation will be for emergency diesel generators and motor vehicles. Based on NRC Reg. Guide 1.108, the annual run time per diesel generator for testing was estimated at 28 hours. This includes the annualized expected duration of actual operation results of approximately 30 h per year for each diesel. Based on typical fuel usage for a diesel generator and two diesel generators, a nominal estimate of 18 m^3/yr (4,756 gal.) for diesel fuel was obtained. Adding a 33% contingency yields a total of 24,000 L (6,340 gal.) of diesel fuel used annually.

To estimate the vehicle usage at the site of the MOX FFF, the number of vehicle trips per day was assumed to be 50 round trips within the site boundaries with a maximum of 3 mile/trip. An average fuel consumption rate of 0.10 gal./mile (3.785 x 10E-4 m^3/mile) and 256 days/yr of use yields a vehicle fuel usage of 14.5 m^3/yr (3,840 gal./yr). Adding a 33% contingency to the nominal annual gasoline use yields 19,330 L (5,100 gal.).

Water use: The ER-W cited water usage data for a 200-MT plant of 57,000 gal./day. These data were adjusted for the MOX FFF to account for the lower plant throughput (100 MT instead of 200 MT) and the difference in the number of employees (350 instead of 225).

There are four major uses of water at the MOX FFF:

- potable water
- process water
- plant cooling water
- fire water

The MOX FFF uses a dry process to fabricate MOX fuels that requires very little process water. The only process water use would be for wet grinding of pellets (should wet grinding be selected), the makeup of "cold" chemical solutions, cement mixing for solid waste packaging, and analytical laboratory usage. A total use of 187 gal./day was estimated for the MOX FFF (see Fig. 5-1), which is half the consumption estimate in the ER-W report.

Potable water at a average flow of 5,600 gal./day will provide water for sanitary purposes (sinks, washrooms, showers, cafeteria, etc.). Usage is based on a plant staff of 350 (see section 6) and a water consumption of 25 gal./day per employee (Ref. 5-6). The daily consumption is a function of workers on site for the day. For 256 work-days the potable water demand is 256 day x 296 employees x 25 gal./day per employee or 1,894,400 gal./yr. For the 111 non work days, the consumption is 111 day x 54 employees x 25 gal./day per employee or 149,850 gal./yr. This gives a potable water total of 2,044, 250 gal./yr or an average of 5,600 gal./day.

The heat dissipation system deals with the facility heating and cooling and the process heat requirements. A cooling tower may be used to cool, by heat exchange, recirculated process cooling water. A cooling tower is shown in this report to conservatively bound the probable water usage. However, it may be possible to use air-to-water heat exchangers in which case a cooling tower would not be used. The values used here are half the ER-W data (Ref. 5-3). The total amount of circulating water will be 1050 gal./min with a total water makeup of 15.75 gal./min (22,680 gal./day), evaporative losses of 10.5 gal./min (15,120 gal./day), drift losses of 2.1 gal./min (3,024 gal./day) and blowdown of 3.15 gal./min (4,536 gal./day). The cooling tower will be rated approximately 5,250,000 Btu/h (1.5 MW).

The fire water supply on site is assumed to consist of two 200,000-gallon grade-level storage tanks. Once the storage tanks are filled with water, only small amounts will be used to check the integrity of the fire protection system on a routine basis (8 gal./day on average). These amounts are negligible as far as the overall water use balance for the plant is concerned. In summary, the estimated water use is as follows:

187 gal./day	process water
5,600 gal./day	sanitary water
22,680 gal./day	makeup water for plant cooling
8 gal./day	fire water systems
===========	
28,475 gal./day	total potable water or 10,393,375 gal./yr

In converting these data to an annual use of water, the ground water demand was rounded off to 10,400,000 gal. (39,733,000 L). A 10% contingency to this value was provided to account for other water uses (e.g., cleaning, maintenance activities), resulting in a total annual consumption of 11,440,000 gal. (43,300,400 L).

No surface water is used.

Process chemicals

The only chemicals of interest used during operation are those involved directly in the fuel pellet/rod/assembly fabrication process and those chemicals used for the reliable operation of support systems.

In the pellet fabrication process, approximately 300 kg of zinc stearate and oxalic acid are used for pressing lubricants. In addition, 300 kg/yr of a binder (such as ethylene glycol) are used, plus a similar amount of pore former, if required.

Cleaning fluids (from the current list of RCRA-approved liquids) are used in the fuel bundle assembly process.

To maintain the pH of the cooling tower circulating water, sulfuric acid is used.

Sodium hydroxide is used to adjust the alkalinity of the makeup water for the closed H_2O cooling system.

Various chemicals are used in the service laboratory, mop water, lab scrubber and for cooling tower blowdowns. The data shown in Table 5-2 are based on the ER-W (Ref. 5-3) and adjusted for the new MOX FFF. The data in Table 3.6-1 of the ER-W are expressed in pounds per day and were converted into pounds per year data assuming operation for 260 day/yr.

Listed as a separate category in this table are combustible materials inventories, most of them being solids.

5.2.2. Radioactive Materials. Both plutonium oxide and depleted uranium oxide are received in powder form and converted into sintered MOX fuel pellets that are loaded into rods and then assembled into fuel bundles.

The average annual consumption of PuO_2 is the equivalent to 3.5 tons of plutonium metal. The average consumption of depleted uranium oxide use for MOX fuel production is approximately 97 tons.

Other radioactive material required for the MOX FFF operation are low-enriched uranium oxide rods and pellets that are received from a uranium fuel vendor and assembled together with the MOX fuel rods to build fuel assemblies. It is assumed that 3.5 tons of plutonium metal will be disposed of annually. And on average, one-third (or 1,167 kg) will be used for BWR MOX fuel rods (which corresponds to 1,323 kg of PuO_2). For an average enrichment of 4% (based on Ref. 5-5), the corresponding MOX fuel weight is 33 tons. Assuming that a UO_2-like BWR fuel assembly contains 23.3 effective MOX rods (a 9 x 9 BWR fuel assembly contains 18 full-length MOX rods and eight partial-length MOX rods) and 32 UO_2 rods, then 45 tons of UO_2 fuel has to be shipped annually, on average, to the MOX FFF for assembly.

Table 5-2. Resource Needs during Operation	
Resource Requirement	**Annual Average Consumption**
UTILITIES	
Electricity	
MWh	12,000 Mwh
Peak demand, Mwh[a]	~2.1 Mwh
Fuel[f]	
Coal, lb (MT)	$1.43x10^6$ (650)
Natural Gas, cubic meter (scf)[b]	0
Diesel oil, L (gal.)	24,000 L (6,340 gal.)
Gasoline, L (gal.)	19,330 L (5,100 gal.)
Water	
Ground, liter (gal)	43,300,400 L (11,440,000 gal.)
Peak demand, liter (gal)[c]	Flat consumption assumed (no surges)
Surface Water	0
PROCESS CHEMICALS[d]	
Gases	
Oxygen[h]	74 m^3 (100 kg)
Argon[e]	5,900 m^3 (20,000 kg)
Nitrogen	15.2 m^3 (18 kg)
Helium[i]	93 m^3 (31 kg) (3,286 ft^3)
Hydrogen	35,900m^3 (3,066 kg)
This table continued on next page.	

Notes: See notes at end of table, next page.

Table 5-2. Resource Needs During Operation (cont.)[g]	
Resource Requirement	**Annual Average Consumption**
PROCESS CHEMICALS (cont.)	
Liquids	
Service laboratory	
H_2SO_4	8 kg (17 lb)
HNO_3	3.5 kg (8 lb)
HCl	2.25 kg (5 lb)
Mop water	
PO_3 (-3) (biodegradable)	18 kg (40 lb)
Cooling water blowdown	
PO_3 (-3) (biodegradable)	85 kg (190 lb)
Lab Scrubber	
$NaNO_3$	500 kg (1,100 lb)
NaOH	76 kg (169 lb)
Binder	
Ethylene glycol	300 kg (670 lb)
Solids	
Lubricant zinc stereate	300 kg (670 lb)

Notes:

a. The peak demand defined as the maximum usage rate during any hour is expressed in terms of MWh.

b. For gases, standard cubic feet is measured at 14.7 psia and 60° F.

c. It is assumed that the water demand is flat over the year and that existing storage tanks can handle any surges in demand should they ever occur.

d. The distinction between process and non-process chemicals is not clearly defined. All chemicals are considered process chemicals for this report. How these chemicals end up in the waste stream is discussed in section 7.

e. Argon is recycled in the sintering furnaces.

f. These are typical combustibles that are often found in the fuel fabrication facility.

g. Note that the masses listed here are annual MOX FFF requirements and not average annual inventories.

h. Oxygen was estimated based on the annual use of ten, 240-ft^3 O_2 cylinders, for laboratory and maintenance purposes.

i. Helium (He_2) was estimated as follows. Helium is used to backfill the MOX fuel pins and for inerting various portions of the MOX fuel fabrication process. It is estimated that approximately 50,000 fuel pins will be fabricated on an annual basis. Assuming a 14 ft (168 in.) fuel pin length, a conservative pin diameter of 0.375 in., and 5% of the pin volume being He_2, then the volume required is 168 in. x (0.187 in.)^2 x π x 50,000 pin/yr x 0.05 = 46,117 in.^{3}, or ~27 ft^3. Adjusted for 300 lb/in.^{2} which is a typical PWR fuel pin backfill pressure, (300 lb/in.^{2} /14.7 lb/in.^{2}) x 27 ft^3 = 544 ft^3 (15.4 m^3). He_2 is used for other process purposes and some will be lost purging the fuel pin transfer mechanisms. It is estimated that the total He_2 requirement will therefore be approximately 6 times this volume or 6 x 15.4 m^3 = 92.5 m^3, or rounded to 93 m^3.

5.3. References

5-1. "Feasibility Assessment of Candidate DOE Sites and Buildings for a Mixed Oxide (MOX) Fuel Fabrication Facility for Disposal of Excess Weapons-Usable Plutonium", DOE/MD-0002, December 1996

5-2. "Accelerator Production of Tritium Programmatic Environmental Impact Statement Input Submittal", SAND93-2094, October 5, 1995

5-3. "Environmental Report, Westinghouse Recycle Fuels Plant", July 1973, AEC Docket Number 70-14323

5-4. "Response to the Surplus Plutonium Disposition Environmental Impact Statement Data Call for a Mixed Oxide Fuel Fabrication Facility Located a the Pantex Plant," LA-UR-97-2067, Los Alamos National Laboratory, Draft issued June, 1998.

5-5. "Optimization and Implementation Study of Plutonium Disposition Using Existing GE Boiling Water Reactors", NEDO-32638, September 30, 1996

5-6. B. Stein, J. S. Reynolds and W. J. McGuinness, "Mechanical and Electrical Equipment for Buildings", John Wiley & Sons, NY, 7th Edition, 1986.

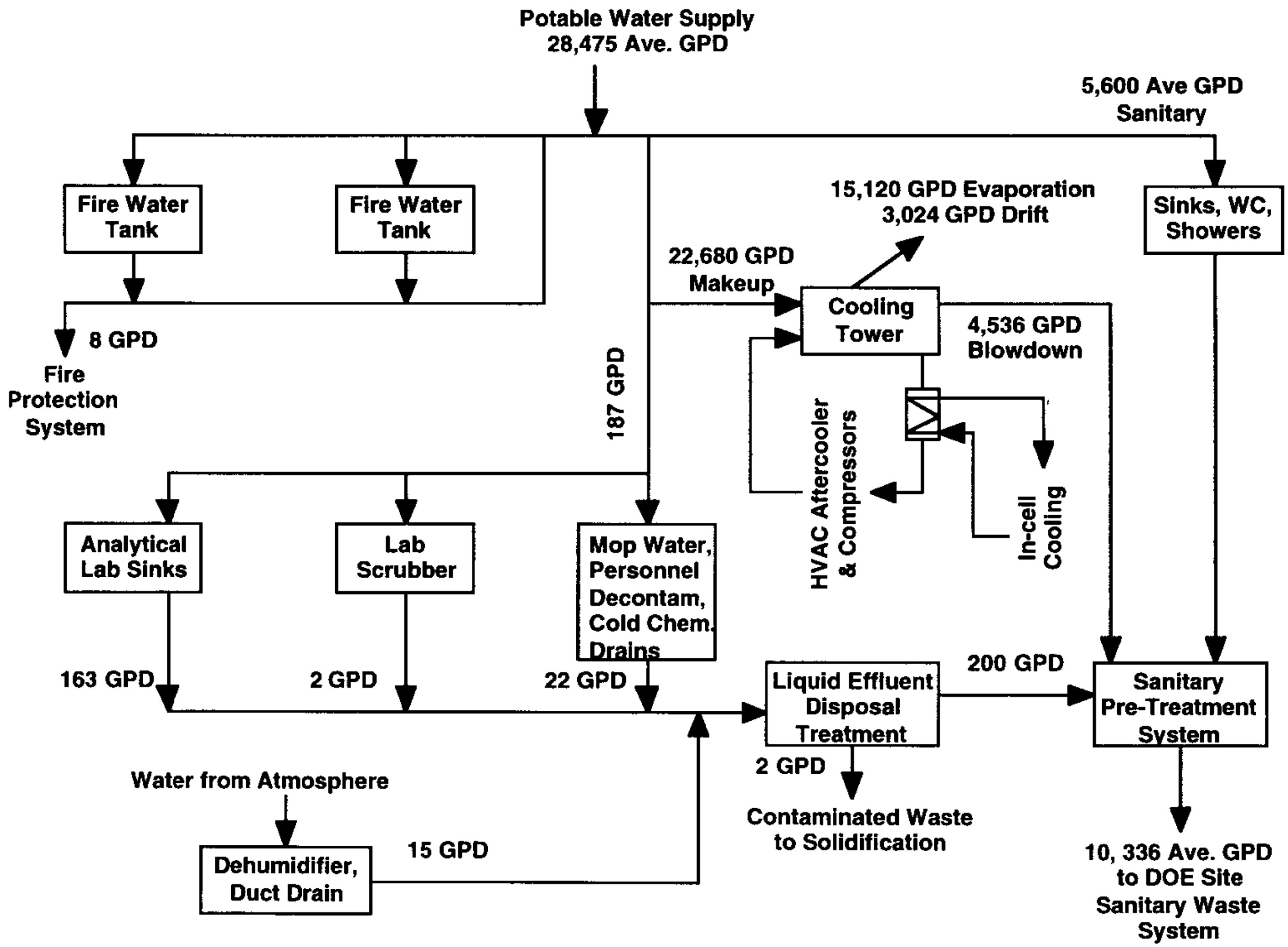


Figure 5-1. MOX FFF Water Balance Diagram

6. EMPLOYMENT NEEDS

6.1. Construction Personnel

For the construction of the MOX FFF, a rolling 4-10 (4 workdays of 10 hours each) or 5-8 (five work days of 8 hours each) construction schedule is assumed. The number of shifts and the employees per shift will vary with the status of the construction. Construction is anticipated to take 3 years, with a cold and hot startup of 1 year each. The data presented in Table 6-1 are taken from LA-UR-95-4442. They result in a total construction effort of 1,480 worker-years, which might be on the high side, both in terms of the number of years for construction and the size of the work force. These construction estimates are for the MOX FFF only and do not include construction personnel for offices, warehouses, or access control facilities. It is not clear if existing or new structures will be used for these purposes.

Table 6-1. Employment During Construction of a New MOX FFF

Construction Year	Number of Workers (Total for year is shown in [ ])	Contingency Construction Workers[a]	Number of Shifts/Day	Employees Per Shift	Number of Construction Days/Year
1	[200] Craft workers 125 Administrative & Management 75	[290] 181 109	1	200	256
2	[350] Craft workers 265 Administrative & Management 85	[507] 384 123	1	350	256
3	[230] Craft workers 150 Administrative & Management 80	[334] 218 116	1	230	256
4 Cold startup	[300] Construction 100 Craft workers 70 Administrative & Management 30 Plant staff 200	[346] 102 44 200	3	200 (day) 60 (2nd) 40 (3rd)	256
5 Hot startup	[400] Construction 100 Craft workers 60 Administrative & Management 40 300 plant staff	[445] 87 58 300	3	275 (day) 75 (2nd) 50 (3rd)	256

Notes:

a. Construction work force values shown in this column represent the addition of a 45% contingency. This column shown per direction of DOE-MD. These values were not used in any of the calculations shown in this report.

These auxiliary facilities can be constructed within a 1-year time period and would be built in the second year of the MOX FFF construction. It is estimated that an additional 50 construction workers (management and craft labor) would be required to construct these facilities.

6.2. Employment Requirements During Operation for a New Facility

The new MOX Fuel Fabrication Facility will employ approximately 350 employees working in two shifts for around-the-clock operation, 5 days/week. Table 6-2.1 through 6-2.4 list the annual employment requirements during operations of a 100-MT/yr MOX Fuel Fabrication Facility. The tables list the workers by their job classifications: process function, hourly and professionals/management job classifications.

This section estimates the total staffing needed for the MOX FFF and estimates the radiation exposure this staff will receive. The staffing estimates are based on pre-conceptual scoping work for the facility and are based on published commercial models (Refs. 6-1, 6-2 and 6-3). The estimates are not specific to any site.

The estimates are intended to be an upper bound for a MOX FFF located at an existing (DOE) site, referred to as a "brown-field" facility. This approach assumes that site management and support structures are in place at the site, which may reduce the employment requirements for the new facility. Although the facility is intended to be operated by a private contractor organization, certain site-related support activities are assumed to be supplied by the existing DOE site contractor organization (e.g., site security, emergency response (such as fire and ambulance responses), meteorological monitoring, etc.).

The maintenance work force was estimated from an assumed maintenance budget, which was based on the expected capital cost of the facility. Management staffing was estimated based on the total work force. Additional workers needed to cover shift time lost to vacations, illness, and training were estimated after the number of shift positions were estimated.

For purposes of estimating the operational work force, a worker was accounted to the facility if more than 80% of the worker's time was needed to support the operation of the facility after the facility was operational. Work efforts that were less than 80% of a worker's time were considered to be part of the support provided by the existing staff at the site.

Assumptions: In addition to the assumptions listed in Appendix A of this data call report, the following assumptions apply to the staffing estimates:

- The MOX facility will be built at an existing DOE site: either at the Pantex Plant, SRS, Hanford Site, or INEEL.
- Sufficient process space is assumed to provide the capability to process 30% more PuO_2 than is originally laid out (spare line).
- Three fuel pellet and fuel pin/bundle fabrication operating lines are assumed, each with independent capabilities. It is assumed that material destined for one type of fuel (e.g., PWR) will be segregated from other types, with the exception that certain portions of the fuel fabrication line may back up or augment an independent line, depending on scheduling and equipment availability.
- Only one clean scrap recycle system and one hot instrument shop is provided.
- Personnel handling SNM must observe the "two-person rule" and work in pairs.
- Operations will be conducted for two 8-h shifts five days per week. Maintenance will be conducted during graveyard shifts and on the weekends. Weekends and the third shift will provide surge capabilities to allow the facility to manufacture fuel to meet various reactor refueling schedules.
- The process will be down for four weeks during the year for inventory and maintenance of critical systems.
- The facility will be under IAEA inspection.
- Automation will be used to reduce exposures, and therefore it will impact staffing.
- SSTs do not have to be unloaded immediately upon arrival and can wait for the next operating shift.
- The process lines are shielded or automated so that no operator receives a dose greater than 2.5 mrem/h during normal operations.
- Process rooms are shielded so that sources in one room do not contribute to exposures in adjacent rooms at levels above background.
- The staffing estimate assumes the shift workers' positions must be covered if the worker is absent because of sickness, vacation, or training. The estimate assumes that the average worker will be absent from the assigned position one week due to illness, three weeks for vacation, and six to seven weeks for training and certification. Roughly 20% additional staffing is needed to cover these absences. Using 20% of shift staffing is a simplification because just increasing staffing by 20% does not ensure that a worker with the proper training and background is available to cover an absent worker. This is particularly true when there is a specialized function performed by a small number of shift workers. Adding 20% may not provide a full-time worker with the proper skills. On the other hand, some absences will be covered with overtime. At this stage of the design and with the current lack of definition of site-specific work rules and

practices, adding 20% to cover shift worker absences is a reasonable estimate. The staffing estimate assumes that there are two 8-h operating shifts, five days per week. Maintenance is performed on the graveyard shift (the third 8-h shift each day) and on weekends. It is possible to schedule an additional operating shift to increase the throughput or to achieve the same throughput using less equipment. Using two operating shifts is conservative. In general, the experience is that graveyard operating shifts are not as productive as the day shifts, because the graveyard operators spend most of their time on maintenance tasks. The staffing estimate also assumes that no replacement coverage is needed for maintenance workers and day workers.

- Transportation of MOX fuel assemblies to the reactor sites will be performed by others, and no staffing allowance is therefore provided.
- The facility will be licensed by the NRC.
- Detailed fuel design, engineering support, fuel and reload licensing, fuel performance evaluation, logistics support, personnel services, security reviews, and other related activities will be performed on a contract basis by third parties or elements of the MOX FFF consortium providing these services.
- See other assumptions in Appendix A

Table 6-2.1. Process Staff **Areas or Process Function**	**Operators per shift**	**Total workers needed for two 5-day shifts**
PuO_2, UO_2 receiving, vault, UO_2 and PuO_2 preparation/delivery to mixing station	4	8
Scrap recovery line, waste packaging and storage	4	8
MOX fuel blending stations	8	16
NDA (includes all incoming and outgoing SNM)	4	8
Bundle fabrication, vault, product storage/shipping	8	16
IAEA safeguard and monitoring	2	4
Waste assay, LLW packaging and certification, LLW shipping, TRU waste packaging and certification, TRU waste shipping	6	12
Miscellaneous processing	2	4
Process supervisors	4	8
Subtotal	42	84
Coverage for vacation, sick leave, and training at 20%	8	16
Total	50	100
Total workers needed for this section		**100**

Table 6-2.2. Other Shift Workers (shift workers other than the process operators needed to support the Process and building operations)

Description	Workers per Operating Shift	Total Workers Needed for Two 5-day Shifts	Worker per Nonoperating Shift (Graveyard) (M-F)	Total Workers to Cover Graveyard and Weekend Shifts
Protective force and supervision	10	20	8	24
Facility systems operators	5	10	3	9
Radiation protection professionals	2	4	2	4
Radiation protection technicians	8	16	4	8
Bioassay, Dosimetry, count lab technicians	3	6		
Computer control technicians	2	4		
Accountability professional	2	4		
Quality assurance professional	2	4		
IAEA escorts	2	4		
Subtotal	36	72	17	45
Coverage for vacation, sick leave and training at 20%	8	16	3	9
Column Totals	**44**	**88**	**20**	**54**
Total workers these column classifications		**88**		**54**
Total workers needed for this section				**142**

Table 6-2.3. Support and Professional Workers

Description	Workers
Support (Professionals)	
Administrative and clerical support	10
Engineering: process, facilities, controls, etc.	14
Analysis laboratory staffing	8
Waste management personnel	2
Regulatory affairs, licensing and safety analysis	12
Transportation professionals	2
Training	6
Quality control	4
Accountability	6
IAEA inspectors	2
IAEA NDA, Sampling and canning crew	4
IAEA manager	1
Maintenance mechanics, electrician, I & C, laborers, etc.	24
Subtotal	**95**
Managers	
Operations manager	1
Engineering manager	1
Facility manager	1
Security manager	1
Maintenance manager	1
Radiation protection manager	1
Accountability manager	1
Quality Assurance Manager	1
Subtotal	**8**
Coverage for vacation, sick leave, and training at 20%—not applicable to this section	0
Total	**103**
Total workers needed for this section	**103**

The number of support and professional workers was estimated based on the assumed maintenance and production requirements of the facility. Based on the assumed schedule, most of the maintenance work will be done during graveyard shifts and on weekends. Minimal maintenance staffing of five craft workers are assigned to operating shifts to handle emergency maintenance. The remaining maintenance staff is assigned to graveyard and weekend shifts. The number of day workers needed to support the facility was estimated. The activities of these workers were identified by reviewing the fact sheets prepared as part of the pre-conceptual design work and by input from the work team. The day worker estimate includes IAEA inspectors. The inspectors are not site employees but are included because they must be provided with space. Work functions with zero workers indicate that the function was considered but did not require 80% of a worker's time once the facility was operational.

Table 6-2.4. Total Workers (Summary of the estimated staffing based on the above sections and shifts)

Description	Number of Employees
Officials and managers (managers and IAEA managers)	10
Technicians (computer control, IAEA escorts analysis lab, IAEA sampling & canning process staff, radiation protection, bioassay)	152
Office and clerical (admin. & clerical)	10
Craft workers (maintenance)	24
Support workers (professionals)	68
Operatives (waste management & facility systems operations)	33
Laborers	4
Service workers (protective force)	44
Total	**345**
Estimated total workers	**350 (rounded up from 345)**

Note: Table 6-2.4 is based, in part, on data provided in Westinghouse Recycle Fuel/Refabrication of MOX Fuel Facility with Capacity of 200 MT/yr of MOX Fuel. (NRC NUREG/CR-2873-V1), dated September 1982; DOE/SF/19683-5 Westinghouse Plutonium Disposition Study, dated April 1994 and NEDO-32361, General Electric Study of Plutonium Disposition, dated June 1994.

Labor Categories used in Table 6-2.4

Officials and Managers. This category includes occupations requiring administrative and managerial personnel who set broad policies, exercise overall responsibility for execution of these policies, and direct individual departments for special phases of the facility's operations. Included in this category are officials, executives, middle management, plant managers, department managers, superintendents, and purchasing agents and buyers.

Professionals. This category includes occupations requiring either a college degree or experience of such kind and amount as to provide a comparable background degree. These professionals are considered experts in a given area or lead teams in completing certain steps in the process. Included in this category are accountants, chemists, engineers, lawyers, metallurgists, health physicists, scientists, and personnel specialists.

Technicians. This category includes occupations requiring a combination of basic scientific knowledge and manual skills. Included in these occupations are computer programmers, drafters, engineering aides, junior engineers, mathematical aides, scientific assistants, and technicians. Also included in this category would be workers trained to the Radiation Worker II level, including press operators, furnace operators, grinder operators, production supervisors, inspectors, SNM accountability clerks, and quality control technicians.

Office and Clerical. This category includes all clerical-type work, regardless of level of difficulty. Included in this category are bookkeepers, office helpers, office machine operators (including computer), shipping and receiving clerks, and typists and secretaries.

Craft Workers (skilled). This category includes manual workers of relatively high skill level having a thorough and comprehensive knowledge of the processes involved in their work. These workers exercise considerable independent judgment and usually receive an extensive period of training. Included in this category are members of the building trades (e.g., carpenters, plumbers, electricians, metalworkers, welders), hourly paid supervisors and lead operators who are not members of management, mechanics, and machinists.

Operatives (semiskilled). This category includes workers who operate machine or processing equipment, or perform other factory-type duties of intermediate skill level that can be mastered in a few weeks and require only limited training. Included in this category are apprentices, operatives, motor operators, painters, truck drivers, forklift operators, equipment assemblers, and packagers.

Laborers (unskilled). This category includes workers in manual occupations who generally require no special training and who perform elementary duties that may be learned in a few days that require the application of little or no independent judgment. Included in this category are garage laborers, groundskeepers, and laborers performing lifting, digging, mixing, loading, and pulling operations.

Service Workers. This category includes workers in both protective and non-protective service occupations. Included in this category for the proposed Immobilization, MOX Fuel Fabrication, and Pit Disassembly and Conversion facilities are guards and protection force personnel.

Methodology for Estimating Worker Radiation Exposures

Radiation exposures to workers operating the MOX FFF has been estimated based on published references (see footnotes after Table 6-4).

Exposure estimates for the staff are estimated in the following tables.
The information provided in the table was adjusted for production capacity and today's conduct of operation requirements.

Table 6-3. Radiation Doses During Construction

Category	Dose	Comments
Average annual dose to all badged workers (mrem)	0	Assumes no radiation sources, except perhaps for NDT work
Maximum dose to badged workers (mrem)	0	
Risk of fatal cancer from radiation sources during construction	NA	

Table 6-4. Radiation Doses During Operations

Category	Dose[a]	Comments
Average Annual dose to all badged workers (mrem)	500[b]	Assumes that design features and administrative controls will maintain exposure to ALARA levels.
Maximum dose to a badged worker (mrem/yr.)	5000	10CFR20

Notes:

a. Based on NRC (10 CFR 20) regulations of 5 rem/yr, 3 rem/quarter maximum and 1.250 rem quarter average allowable.

b. Facility to be designed so that worker exposure is be below 500 mrem/yr. Comparable MELOX design experience is 500 mrem/yr (Refs. 6-4 and 6-5).

6.3. References

6-1. Westinghouse Recycle Fuel/Refabrication of MOX Fuel Facility with Capacity of 200 MT/yr of MOX Fuel. (NRC NUREG/CR-2873-V1), dated September 1982.

6-2. DOE/SF/19683-5 Westinghouse Plutonium Disposition Study, dated April 1994 .

6-3 NEDO-32361, General Electric Study of Plutonium Disposition, dated June 1994.

6-4. Hass, D., et al, "Mixed Oxide Fuel Fabrication Technology and Experience at the Belgonucleaire and CFCa Plants and Further Developments for the MELOX Plant", *Nuclear Technology*, No. 106, April 1994.

6-5. Ducroux, R. and Lorenzelli, R., "Integration of Radiation Protection to the MELOX Plant Design", Radioprotection (Bulletin de la Societe Francaise de Radioprotection) (France) Apr-June 1992 V27, no. 2, p129-141.

7. WASTES, EMISSIONS, AND EXPOSURES AT THE SRS MOX FFF

The wastes, emissions, and exposures at the SRS MOX FFF are divided into construction and operational data. Section 7.1 will discuss data needs for the construction phase, and section 7.2 will discuss operational data needs. The data presented in the following sections are considered representative estimates, based on reviews of various MOX FFF designs and operational analyses done during the last few decades.

The following general definitions of waste classifications apply:

Hazardous Waste:

Under the Resource Conservation and Recovery Act (RCRA), hazardous waste is defined as a solid waste or combination of solid wastes, which because of its quantity, concentration, or physical, chemical, or infectious characteristics may (a) cause or significantly contribute to an increase in mortality or an increase in serious, irreversible, or incapacitating reversible illness, or (b) pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, disposed of, or otherwise managed. Hazardous wastes are defined in the RCRA regulations by their appearance on certain lists or by their exhibiting at least one of the following characteristics, also defined in the RCRA regulations: (1) ignitability, (2) corrosivity, (3) reactivity, or (4) toxicity. Source, special nuclear material, and by-product material, as defined by the Atomic Energy Act, are specifically excluded from the definition of solid waste. RCRA defines a "solid" waste to include solid, liquid, semisolid, or contained gaseous material.

Low-Level Waste:

LLW is waste that contains radioactivity and is not classified as high-level waste, transuranic waste, or spent nuclear fuel. Test specimens of fissionable material irradiated for research and development only, and not for production of power or plutonium, may be classified as low-level waste, provided the concentration of transuranic radionuclides (atomic number greater than 92) is less than 100 nCi/g of waste. Low-level waste is subject to the provisions of the Atomic Energy Act.

Low-Level Mixed Waste:

Low-level mixed waste is waste that contains both hazardous (as defined and regulated by RCRA) and low-level radioactive components.

Transuranic (TRU) Waste:

TRU waste is waste that is contaminated with alpha-emitting transuranic isotopes (atomic numbers greater than 92) with half-lives greater than 20 years and in concentrations greater that 100 nCi/g at the time of assay, except for high-level waste and other waste specifically excluded by DOE, EPA, and/or NRC.

High-Level Waste:

High-level waste is the highly radioactive waste material that results from the reprocessing of spent nuclear fuel, including liquid waste produced directly from reprocessing and any solid waste derived from the liquid that contains a combination of transuranic and fission product nuclides in quantities that require permanent isolation.

The operation of the MOX FFF will not generate any high-level waste. No radioactive waste will be generated during the construction phase.

The following waste categories are addressed:

1. TRU waste
2. Mixed TRU waste
3. Low-level waste
4. Mixed low-level waste
5. Hazardous waste
6. Nonhazardous waste (sanitary)
7. Nonhazardous waste (other)

7.1. Construction-Generated Waste

No radioactive wastes are generated during construction. The only wastes generated are liquid and solid hazardous wastes, solid and liquid nonhazardous wastes, and air pollutants emitted during construction.

See the Definitions section of this report for waste definitions.

1. Hazardous wastes

Hazardous wastes are wastes that are listed in the RCRA regulations and are ignitable, corrosive, reactive, and/or toxic.

Liquid hazardous wastes generated during construction consist of nonradioactive materials such as cleaning solvents, motor oils, gasoline and diesel fuel, hydraulic fluids from mechanical equipment, antifreeze solutions, and paint. In addition, chemicals used for the chemical flush of cooling systems (e.g., phosphoric acid, sodium phosphate) are included here even though it is common practice to recycle and filter them.

Solid hazardous wastes generated during construction consist of nonradioactive materials such as wipes contaminated with oil, lubricants, and cleaning solvents.

All hazardous liquid wastes are collected in DOT-approved containers and shipped to an authorized RCRA disposal site.

2. Nonhazardous waste (sanitary)

The sanitary wastes generated include nonradioactive and nonhazardous wastes from showers, urinals, water closets and lavatories, sink drainage, and floor washings, as well as run-off from stabilizing dust by water sprinklers on roads and construction areas.

Sanitary wastes will be treated in accordance with National Pollutant Discharge Elimination (NPDES) requirements. The liquid effluents and solid wastes will be sampled before discharge. Analyses of the liquids and solids will include determination of radioactive materials, tritium, and heavy metals. The analyses are performed mainly during the startup period.

After treatment, sanitary wastes will be sent to drainage water channels.

3. Nonhazardous wastes (non sanitary)

The main constituents of the solid nonhazardous wastes generated during construction are concrete and steel wastes. It is assumed that 5% of the concrete and steel used will be waste. In addition to those wastes, other solid industrial waste and trash are generated during construction of the facility that are sent to sanitary or industrial landfills off site.

The main sources of liquid nonhazardous wastes are waste water and dewatering.

Storm water collected from roofs and paved areas will be sampled periodically for radioactive content. During the later stages of construction water from room heating will be returned to the heating unit with no contamination.

7.1.1. Construction-Generated Liquid and Solid Wastes

Hazardous liquid waste

It is assumed that in the last year of construction, 5,000 L of phosphoric acid and 5,000 L of sodium phosphate will be used for the chemical flush of the cooling system and stored as hazardous waste. It is assumed that in addition to this waste, there are approximately 500 L/yr of waste generated that contain oil and oil-contaminated liquids, gasoline, hydraulic fluids, lubricants, cleaning solvents, paint remnants, and antifreeze. The total liquid hazardous waste generated during the 3-yr construction period is 11,500 L (3,040 gal.).

It is assumed that during cold startup, the amount of liquid hazardous waste equals 10% of the corresponding operational waste value, i.e., 100 L. During hot startup, it is assumed that the waste amount corresponds to 50% of the operational waste value, i.e., 500 L.

The total amount of hazardous liquid waste during the 5-yr construction and startup period is 12,100 L (3,200 gal.).

Note: The data shown in Table 7-1 under "Annual Volume" are the maximum annual volumes of hazardous wastes.

Hazardous solid waste

Only small amounts of solid hazardous waste are produced during the 5-yr construction and startup phase. It is assumed that the amount of hazardous wastes generated during construction will be less than 2 m^3 (60 ft^3).

Nonhazardous wastes

The solid and liquid nonhazardous wastes generated during construction include concrete and steel construction waste materials and sanitary wastewater.

Nonhazardous waste (sanitary)

Over the 5-yr construction and startup period, water use was estimated as follows (see Table 5-1):

		gallons
nominal for personal use:	construction	199,680
	cold and hot startup	3,328,000
use for concrete (assumes local batch plant)		405,000
process water, hot startup		8,349,375
contingency for 3 year construction (includes 6,000 gal. used to wash neutralized muriatic acid off concrete after etching)		302,340
	Total (gal.)	~12,584,000
	or in L	~47,630,000

It is assumed that all of the water for personal use ends up as sanitary water during cold and hot startup. It is assumed that of the water for other uses, as shown on Fig. 5-1, becomes sanitary waste during hot startup. It is also assumed that one half of the contingency water becomes honhazardous sanitary waste. The nonhazardous (sanitary) waste is estimated to be

one half of contingency water (gal.)	151,170
personal use (cold startup, gal.))	768,000
hot startup (10,336 avg. gal./day x 365 day/yr)	3,772,640
Total nonhazardous sanitary (gal.)	~4,692,000
or in L	~17,760,000

It should be noted that most the personal water use occurs during the startup period. If the nonhazardous sanitary liquid waste were to be limited to the 3-yr construction period, only 162,120 gal. (~613,000,000 L) of sanitary waste would have to be disposed of.

Solid sanitary wastes include shipping containers, personal waste (e.g., newspapers, lunch bags) and trash (e.g., shipping containers). Waste volume is based on 14 lb per person per day during construction with a volume equivalent is 5.5 lb/ft^3 (Ref. 7-1.)

Nonhazardous solid waste

It is assumed that 5% of the 9,216 m^3 (12,054 yd^3) concrete used during construction ends up as solid waste, i.e., 460 m^3.

It is assumed that of the 3,611 tons of steel used during the construction period, less than 180 tons will end up as solid waste, most of which, however, will be recycled. It is assumed that the all of the 2,000 m^3 of lumber would go to waste.

Table 7-1. Estimated Waste Generated during Construction of a New MOX FFF at SRS

WASTE CATEGORY	ANNUAL VOLUME	TOTAL ESTIMATED VOLUME
Hazardous waste		
liquid	10,500 L (2,774 gal.)[a]	12,100 L (3,200 gal.)
solid	2 m^3 (1.6 yd^3)[a]	2 m^3 (1.6 yd^3)
Nonhazardous waste (Sanitary)		
liquid (avg. 5 yr basis)	3,552,000 L (938,400 gal.)	17,760,000 L (4,692,000 gal.)
solid[c]	931,844 lb	2,795,530 lb
cubic feet[c]	169,400 ft^3	508,300 ft^3
Nonhazardous waste (Other)		
liquid	0 gal.	0 gal.
solid		
concrete	1153 m^3 [c]	460 m^3
steel	60 MT (6.9 m^3)[c]	180 MT (21 m^3)
lumber[b]	666 m^3 [c]	2,000 m^3

Notes:
a. This is the maximum annual hazardous waste volume.
b. All lumber used ends up as waste
c. Annualized over three years, as most construction waste is generated during this period. Note: Nonhazardous solid sanitary waste is shown in this table

for 3 years but should be scaled to 5 years, on an annual basis to address startup period.

7.1.2. Air Emissions during Construction of a New MOX FFF

The principal sources of air emissions during construction are

- fugitive dust from land clearing, site preparation, excavation and other construction activities
- exhaust from construction equipment
- vehicles delivering construction materials and carrying construction workers

The basis for these emissions is shown below.

EPA AP-42	Construction Diesel Fuel ($kg/10^3$ L)	Operating Natural Gas Burner ($kg/10^6$ ft^3 NG)	Operating Coal Boiler (kg/MT coal)	Operating Diesel Generator ($kg/10^3$ L)	Operating Oil Fuel ($kg/10^3$ L)
CO	14.22	27.7	2.5	15.6	0.6
NO_x	36.72	37.7	6.85	72.4	2.4
PM_{10}	2.809	6.35	0.33	5.09	0.12
SO_x	3.735	0.272	38.0	4.76	17.04
HC[a]	2.906	-	-	-	-
VOC	-	-	0	5.91	-
TOC	-	2.63	-	-	0.067

Note: a. Hydrocarbon emission

The air emissions listed in Table 7-2 are based on diesel fuel, and the values are based on the methodology described in section 7.2.2, Air Emissions during Operation of the MOX FFF.

TABLE 7-2. Air Emissions during Construction of a New MOX FFF		
Pollutant	**Annual Emissions (kilograms)**	**Average Concentration (g/m^3)**
Carbon monoxide	3200	2.2
Oxides of nitrogen (NO_X)	8400	5.5
Particulate matter (PM-10)	640	0.43
Oxides of sulfur (SO_X)	850	0.53
Volatile organic compounds	660[a]	0.4
Hazardous air pollutants (e.g., lead, benzene, hexane, asbestos)	<1	n/a

<u>**Basis for Diesel Fuel for Construction Equipment**</u>

SRS 228,000 L/yr for 3 yr

Actual annual emissions:

CO	(14.22 kg/1000 L)(228,000 L) = 3242 kg CO
NO_x	(36.72 kg/1000 L)(228,000 L) = 8372 kg NO_x
PM_{10}	(2.809 kg/1000 L)(228,000 L) = 640 kg PM_{10}
SO_x	(3.735 kg/1000 L)(228,000 L) = 852 kg SO_x
HC	(2.906 kg/1000 L)(228,000 L) = 663 kg HC

Concentrations:

Same as "OPERATING - Diesel/Gasoline Fuel for Motor Vehicles" in section 7.2.2.

7.1.3. Radioactive Releases from Construction of a New MOX FFF

During construction of the MOX FFF, no TRU, mixed TRU, low-level, or low-level mixed and solid hazardous wastes are produced.

Table 7-3. Radioactive Releases from Construction of New MOX FFF			
Radionuclide	**Release**	**Average Release Height, m (ft)**	**Release Point Coordinates (Latitude, Longitude)**
Air	0	n/a	n/a
Surface water	0	n/a	n/a

7.2. Operation-Generated Wastes

The MOX fuel fabrication process neither receives nor produces any high-level waste. High-level waste is normally the result of reprocessing nuclear fuel used to make nuclear weapons or nuclear fuel.

Section 4 describes the MOX fuel fabrication process and lists in detail the waste generation in the following areas:

- materials receiving and storage
- feed materials preparation
- fuel pellet fabrication
- fuel rod fabrication
- fuel bundle assembly
- process materials recycle
- waste management systems

The waste classifications used in this report for operation-generated wastes follow the definitions listed above and distinguish between the following waste classes:

1. Transuranic (TRU) waste

TRU wastes are radioactive wastes contaminated with alpha-emitting elements with a higher atomic number than uranium, half-lives greater than twenty years, and in concentrations greater than 100 nCi/g. Such wastes primarily result from plutonium processing operations. Generally, little or no shielding is required ("contact-handled" TRU waste).

All TRU wastes discharged from the facility are in solid form. TRU wastes containing greater than 100 nCi/g of plutonium will be appropriately packaged and transferred to the DOE for disposal.

2. Low-level wastes

Low-level radioactive wastes are those that contain less than 100 nCi/g of plutonium. This waste will be collected separately and assayed to ensure that the waste package is below the 100 nCi/g level. As in the case of TRU wastes, it will be transferred to the DOE for disposal.

3. Mixed transuranic wastes

Hazardous wastes are defined as wastes that are listed in the RCRA regulations and that are ignitable, corrosive, reactive, and/or toxic. Mixed TRU wastes are those that have hazardous and radioactive components above 100 nCi/g. Mixed wastes include solvents, lead, and scintillation vials. These wastes will be appropriately packaged and transferred to the DOE for disposal.

4. Mixed low-level wastes

Hazardous wastes are defined as wastes that are listed in the RCRA regulations and that are ignitable, corrosive, reactive, and/or toxic. Mixed low-level wastes are those that have hazardous and radioactive components of less than 100 nCi/g. These wastes will be appropriately packaged and transferred to the DOE for disposal.

5. Hazardous wastes

Hazardous wastes are defined as wastes that are listed in the RCRA regulations and that are ignitable, corrosive, reactive, and/or toxic. They are kept separate from the other waste forms.

Hazardous solid wastes consist of nonradioactive material such as lead packing and wipes contaminated with oils, lubricants, batteries, and cleaning solvents. Hazardous solid wastes are compacted and sent to an authorized RCRA disposal site.

Hazardous liquid wastes generated from the facility include cleaning solvents, vacuum pump oils, film processing fluids, hydraulic fluids from mechanical equipment, antifreeze solutions, and paint. All hazardous liquid wastes are collected in DOT-approved containers and shipped to an authorized RCRA disposal site (i.e., they do not enter LET system).

6. Nonhazardous waste (sanitary)

The sanitary wastes generated include nonradioactive and nonhazardous discharges from sinks in chemical laboratories that handle nonradioactive materials, wastes from showers, urinals, water closets and lavatories, sink drainage, and floor washings.

Sanitary wastes will be treated in accordance NPDES requirements. The liquid effluents will be sampled before discharge. Analyses of the liquids and solids will include determination of radioactive materials, tritium, and heavy metals.

7. Nonhazardous wastes (nonsanitary)

Among these wastes are solid industrial wastes from utility and maintenance operations, machine shop cuttings, and trash generated from the facility are sent to sanitary or industrial landfills off site. The water used in the process is subsequently decontaminated to a point where it could be released to the environment.

Potentially, some of this water could be used to mix with cement to immobilize TRU wastes.

Storm water collected from roofs and paved areas will be sampled periodically for radioactive content. Building heating system water, assuming a hot water facility heating system, will be returned to the heating unit with no contamination because these types of systems are closed systems.

No liquid recyclable wastes external to the facility will be generated. Only recycled office supplies such as paper, packaging, and toner cartridges will be generated. No solids from the process buildings will be recycled outside the facility.

Note: Waste treatment and disposal for MOX FFF as described in the open literature does not follow this waste classification but distinguishes only between radioactive and nonradioactive wastes, airborne effluents, liquid effluents and solid wastes. To assign the wastes to the categories just listed is, therefore, somewhat ambiguous, especially in regard to the distinction between mixed and nonmixed wastes.

7.2.1. Wastes Generated during Operation of the MOX FFF

7.2.1.1. Waste Treatment Systems. The waste treatment systems, described in greater detail in section 4, consist of the following systems:

1. Liquid Effluent Treatment (LET) system,
2. Liquid Waste Treatment (LWT) system,
3. Miscellaneous Waste Treatment (MWT) system, and the
4. Sanitary Water Treatment system.

The LET system receives all liquid waste streams from the fuel fabrication complex for analysis and treatment before any liquid effluents are sent to the sanitary water treatment system.

The LWT and MWT systems deal with contaminated and potentially contaminated wastes to recover plutonium, process the wastes, and reduce their volume. TRU, mixed TRU, and low-level wastes can be solidified and drummed, and liquid wastes are rendered acceptable to the DOE site sanitary waste treatment system.

One of the key objectives for the waste treatment system on which the contaminated waste data in Table 7-4.2 are based was the minimization of liquid wastes and the concurrent emphasis on solidified waste. Therefore, the liquid contaminated waste volumes are very small.

Organic wastes are sent to the MWT where they are collected and filter-processed to remove particulate material. The collected precipitate is sent to the roasting box for further treatment. The small amount of residual organic liquid is transferred to a

55-gal. drum containing an absorbent and placed in a shipping container for eventual disposal.

The sanitary water treatment system accepts liquid discharges for treatment from the LWT and LET systems as well as from the conventional sanitary system. In addition, the water from cooling tower blowdown is also sent to the sanitary water treatment system.

Hazardous wastes are collected in DOT-approved containers and shipped to an authorized RCRA disposal site.

Nonhazardous liquid sanitary wastes are sent to the sanitary waste treatment system and then released.

Other nonhazardous wastes are collected separately and sent to a sanitary or industrial landfill off site.

7.2.1.2. Waste Quantities. The estimation of the waste quantities for TRU and mixed TRU wastes, LLW, and mixed LLW waste were largely based on extrapolation from data presented in the Westinghouse Plutonium Disposition Study of 1994 (Ref. 7-2) and the Environmental Report for a MOX fuel fabrication facility Westinghouse prepared for the NRC in 1973 (Ref. 7-3). The estimation of hazardous waste quantities is largely based on engineering judgment. The nonhazardous sanitary waste volumes are based on the water use allocations described in section 5.2. Other nonhazardous waste quantities are again based largely on engineering judgment.

There are no documents in the open literature that show breakdowns in waste volumes for the different waste categories listed above. The data cited from the open literature could not be independently validated, either through independent design and analysis or through supporting evidence from other FFFs. In case of the former, a MOX FFF has not been developed yet; in case of the latter, open literature publications contain very few details on waste generation and disposal. However, efforts were made not to underestimate the expected waste quantities for a representative MOX FFF.

Whenever waste data are presented, they depend on the particular waste treatment systems chosen for a particular MOX fuel fabrication plant design, which in turn reflects the requirements it had to meet. The degree of internal recycle and waste volume reduction has a significant impact on the waste quantities that need to be disposed of. The interrelationship between the three treatment systems (LET, LWT, and MWT) selected here as the basis for the waste estimates presented in Table 7-4, does not permit direct tracing of all input materials to the plant through the fabrication process until waste disposal. While this would be a complex undertaking if a detailed MOX FFF design and operations description were available, it is an impossible task in the absence of such detailed information. The emphasis was, therefore, on ensuring the reasonableness of the data cited.

TRU, Mixed TRU, Low-Level and Mixed Low-Level Waste

As shown in Table 4-1, plutonium-contaminated wastes can be generated in varying concentrations in all areas of the fabrication plant. Plutonium scrap is of particular importance because it can contain plutonium in enrichments of 5% or more. It is assumed that 10% of the plutonium used in the MOX FFF will end up as scrap plutonium with nearly all of it being recycled except for a small amount of dirty scrap. Dirty scrap is mixed oxide fuel that has become mixed with nonfuel material and, therefore, cannot be recycled as clean scrap. Materials falling into this category are

- contaminated MO_2 and PuO_2 powder, MO_2 pellets, chips
- sweepings
- analytical and quality control samples
- liquid wastes from analytical lab
- filter elements from waste treatment facilities

It is assumed that less than 0.5% of the plutonium used will end up as dirty scrap. For a 100-MT MOX facility, this translates into 500 kg/yr of dirty scrap containing approximately 25 kg of plutonium. This plutonium-containing waste will be returned to DOE for disposal.

Assuming the waste repository is the WIPP, the waste acceptance criterion of 200 gram (max.) of plutonium per 55 gal. drum translates to approximately 0.1 wt % of plutonium in the waste drums. Dirty scrap does not always meet this disposition criterion. Furthermore, all waste destined for disposal would also have to meet any other criteria defined by the waste depository plus DOT shipping requirements before actual shipment.

As shown in Table 4-1, contaminated waste is generated not only in the MOX fabrication process steps of powder preparation, pellet fabrication, rod loading, and assembly but all through the MOX FFF, although in smaller quantities/concentrations.

To provide a perspective for the existing database on contaminated waste quantities, the following sources of information will be cited:

1. GESMO data

In the Final Generic Environmental Statement on the Use of Recycled Plutonium in Mixed Oxide Fuel in Light Water Reactors, referred to as GESMO (Ref. 7-4), the solid radioactive waste volume and its PuO_2 content are summarized as follows:

Table 7-3.1. Generic Environmental Statement Data

Waste Stream	Approx. Volume before Packaging (ft^3)	PuO_2 Content (kg)
HEPA filters	710	13
Solidified liquid waste	1,900	0.7
General process waste	5,000	7.8
Major process components	2,500	0.5
Total	~10,000 ft^3	22 kg

These data are based on a MOX FFF with a 360-MT MOX fuel annual throughput. Because of the short lifetime of the MOX FFF and the requirement that equipment lasts through the life of the facility, only small amounts of radioactive waste are expected under the major process component category.

For a 100-MT facility, based on these data the following adjustments were made to the data in the GESMO report:

Table 7-3.2. GESMO Data Adjusted for 100-MT MOX FFF

Waste Stream	Approx. Volume before Packaging (ft^3)	PuO_2 Content (kg)
HEPA filters:	250	4.6
Solidified liquid waste	700	0.3
General process waste	2,000	2.8
Total Radioactive Waste:	2,950	7.7

The plutonium content in this waste estimate is very low and results from the dirty scrap recycle at the MOX plant through nitric acid dissolution, solvent extraction to recover nitrate solution, and calcination. Even though it was assumed that GESMO would generate 1.7% dirty scrap, the on-site wet recycle permits a significant reduction in the plutonium losses.

2. Westinghouse PDS data (Ref. 7-2)

For a 150-MT MOX FFF without dirty scrap recycle, Westinghouse has estimated the following waste data (Ref. 7-2):

Table 7-3.3. Waste Types and Estimated Volumes		
Waste Process System	**Waste Type for Shipment**	**Waste Volume (ft^3)**
Misc. waste treatment	Low-level waste, unmixed Low-level waste, mixed TRU waste, unmixed TRU, mixed	1,190 (170 drums) 76 (10 drums) 1,205 (175 drums) 135 (20 drums)
Liquid waste treatment	TRU waste, unmixed TRU waste, mixed	260 (36 concreted drums) 30 (4 concreted drums)

The total contaminated waste volume is estimated to be 2,896 ft^3.

The estimated plutonium content in the waste shown below amounts to nearly 50 kg contained in TRU waste. Low-level waste contains only negligible amounts of plutonium, which is consistent with its waste classification, namely plutonium contents of less than 100 nCi/g waste.

As expected, the differences between the GESMO and Westinghouse PDS data in the estimated plutonium content in the waste are substantial because of dirty scrap recycle in one plant but not the other.

Table 7-3.4. Estimated Plutonium Content in Waste, Westinghouse PDS 1994						
Waste Process Systems	**Waste Streams**	**Isotope**				
		Pu-238	Pu-239	Pu-240	Pu-241	Pu-242
Misc. waste treatment	Low-level waste, kg	neg.	neg.	neg.	neg.	neg.
	TRU & mixed wastes, kg	0.02	37.44	2.36	0.16	0.02
Liquid waste treatment	TRU & mixed wastes, kg	0.004	7.488	0.472	0.032	0.004
	Total, kg	0.024	44.928	2.832	0.192	0.024

3. Environmental Report Westinghouse Recycle Fuels Plant (Ref. 7-3)

Reference 7-3 describes in great detail the generation and treatment of contaminated wastes in a 200-MT MOX FFF without dirty scrap recycle. It uses for waste treatment the same facilities (LET, LWT, MWT) as described in the Westinghouse PDS of 1994. The following waste quantities are cited:

Table 7-3.5. Waste Quantities

Estimated Volumes (Ref. 7-3)	Waste (ft^3)	Drums/year
Miscellaneous waste treatment	1,727 956	235 compactible 130 noncompactible
Liquid waste treatment	515	70 solidified waste
Total	3,200	435 drums/yr

Normalizing this waste volume to a 100-MT MOX FFF yields a waste quantity for disposal of approximately 1,600 ft^3.

4. Summary and Conclusions

The unnormalized and normalized waste quantities cited in different reports are shown below:

Table 7-3.6. Contaminated Waste Summary

	GESMO	Westinghouse PDS	Westinghouse ER
Throughput, MT/yr	360	150	200
Dirty scrap wet recycle	yes	no	no
Waste volume, ft^3 [a]	10,000	2,900	3,160
Normalized waste volume, ft^3 [b]	3,000	2,000	1,600

Notes:

a This waste volume has been estimated for the MOX fuel throughput cited in the respective reports.

b This waste volume has been adjusted for a 100 MT MOX FFF.

Although these data from different sources often vary by as much as a factor of 2 from the lowest to the highest volume, such differences are not unexpected. The MOX FFF has not been defined yet to the point at which criteria for recovery/recycle have been established. It is expected that use of wet vs. dry processes yields generally higher waste volumes; this is confirmed by the data although no more than the trend should be noticed here.

It is recommended to use as contaminated waste quantities those cited in the Westinghouse PDS for a 150-MT MOX FFF (Ref. 7-2), but add small amounts of liquid wastes for the following reasons.

The waste treatment processes described above focus on waste minimization and solidification and show that no liquid contaminated waste would leave the plant. However, it is conceivable that considering the very low quantities of plutonium contained in contaminated (TRU and low-level) wastes, it might be prudent to dispose of some of the mixed LLW and low-level waste in liquid form rather than trying to solidify all these wastes and recycling them between the LWT and MWT systems to ultimately solidify all liquid wastes. It is assumed that 1% of the solid waste corresponds to the amount of liquid LLW or mixed low-level waste.

Note: if waste contains more than 100 nCi plutonium per gram of waste, this waste is classified as TRU waste; if it is less than 100 nCi per gram, it is classified as low-level waste. A concentration of 100 nCi plutonium per gram of waste corresponds to a plutonium content of less than 0.5 microgram per gram.

The estimated contaminated wastes are shown below:

Table 7-3.7. Contaminated Waste Estimates for a 100-MT MOX FFF

Waste Form	Volume, ft^3	Volume, m^3	Number of Drums [a]
TRU waste			
solid	1,465	41.5	211
liquid	15	0.4	2
Mixed TRU			
solid	165	4.67	24
liquid	1	0.05	1
LLW			
solid	1,190	33.7	170
liquid	12	0.3	2
Mixed LLW			
solid	76	2.15	10
liquid	1	0.02	1

Note: 55-gal. (208-L) drums are assumed.

It is assumed that the disposal of all contaminated wastes would be DOE's responsibility.

Hazardous Wastes

Hazardous wastes as defined above are collected and treated separately from all other wastes. They are generated in small quantities only. It is assumed that only 1 m^3 of liquid and 0.2 m^3 of solid hazardous waste are generated per year.

Table 7-3.8. Hazardous Waste Estimate for a 100 MT MOX FFF

Solid	200 L	50 gal.	7 ft^3
Liquid	1000 L	250 gal.	35 ft^3

Nonhazardous Wastes

Nonhazardous wastes are classified as either "sanitary nonhazardous wastes" or "other nonhazardous wastes."

It is assumed that the water supplied to the MOX FFF is of standard quality and does not require additional treatment except for a small amount of water that might have to be processed through a small deionizer for laboratory use.

Nonhazardous sanitary wastes

1. liquid

The nonhazardous sanitary waste consists of an average 5,600 gal./day of sanitary water that had been allocated for personal use, 200 gal./day from the LET system, plus 4,536 gal./day from cooling tower blowdown for a total average of 10,336 gal./day entering the sanitary water treatment system.

The process water includes nonradioactive, nonhazardous discharges from sinks in chemical laboratories that handle no radioisotopes, such as wastes from showers, urinals, water closets and lavatories, sink drainage, and floor mopping. As shown in Fig. 5-1, a total of 187 gal./day is allocated for these activities. These effluents enter the LET system before they are discharged to the Sanitary Water Treatment system. This waste water represents less than 1% of the total liquid nonhazardous sanitary wastes.

Assuming the 350 plant employees work the shift schedules shown in section 6, the following annual sanitary waste water quantities are used:

Table 7-3.9. Nonhazardous Liquid Sanitary Waste (Annual Average)		
Sanitary water	7,737,000L	2,044,000 gal.
Process water	276,000 L	73,000 gal.
Blowdown operations	6,268,000 L	1,656,000 gal.
Total amount of nonhazardous sanitary water entering the sanitary water treatment system	~14,281,000 L	~3,774,000 gal.

Note: Included in the process wastes are nonradioactive liquid chemical wastes from laboratory sinks, detergents from floor scrubbing, and small amounts of chemicals used as lab scrubber. (The amount of solids from the secondary cooling water blowdown is listed below). These streams flow into the sanitary waste treatment system after treatment in the LET system. The estimated chemical concentrations discharged to the sanitary system are shown below:

Table 7-3.10. Estimated Chemical Wastes Discharged to the Sanitary System

Waste	lb/day	gal./day
Laboratory Sink Drain		162
H_2SO_4	0.07	
HNO_3	0.03	
HCL	0.02	
Mop Water		29
orthophosphate (biodegradable)	0.15	
Cooling Tower Blowdown		4,536
orthophosphate (biodegradable)	0.75	
Total solids	3.4	
Lab Scrubber		3
$NaNO_3$	4.25	
NaOH	0.62	

The chemicals entering the LET system are already highly diluted. The pH level of the effluents is adjusted by acid and caustic solution additions from their respective supply tanks. If the effluents are within specific pH levels and show sufficiently low radioactivity levels they are discharged to the sanitary water treatment system.

After leaving the sanitary water treatment system, they are even further diluted to chemical concentrations in the milligram per liter range (Ref. 7-3, Table 5.4-1).

2. Solid

The effluents from janitorial activities sent to the LET system will be separately collected and treated because of the quantity of dirt and sediments present. It is estimated that those solid nonhazardous sanitary wastes will amount to less than 1 m^3 per year.

Other nonhazardous wastes

1. Solid

Wastes that fall into this category include solids from the cooling tower blowdowns (approximately 900 lb/yr), solid industrial wastes and trash generated at the facility as well as wastes from office operations. It has been estimated by Westinghouse (Ref. 7-2) that for a 150-MT MOX FFF, the amount of combustible waste (paper, cloth, wipes, etc.) will amount to 2,800 ft^3 (about 100 m^3) per year. It is conceivable that most of this waste would be sent to an incinerator, where its volume would be greatly reduced.

However, for this report it has been conservatively assumed that annually <150 m^3 of solid (other) nonhazardous waste is generated.

2. Liquid

It is conceivable that the processing of solid (other) nonhazardous wastes will require water that would add to the water ultimately sent to the sanitary water treatment system. However, this amount is expected to be very small. As a MOX FFF is developed, it is conceivable that internal water recycle can be employed to deal with the processing of such solid wastes.

It is assumed that the amount of liquid (other) nonhazardous waste will be <500 liter per year.

Waste Summary and Conclusions

The waste quantities presented in Table 7-4.2 were obtained for a waste treatment system based on a Westinghouse design that dealt with contaminated and potentially contaminated wastes and consisted of (1) a treatment of all liquid effluents from the plant in the LET system, (2) a treatment of contaminated liquid wastes obtained from the LET system, in the LWT system, (3) a treatment of all solid and certain contaminated liquid lab wastes in the MWT system, and (4) the treatment of all liquids discharged to the plant drain system in the sanitary water treatment system. Hazardous wastes were collected separately and did not enter this waste treatment system. Sanitary wastes go directly to the sanitary waste treatment system.

Because the MOX fuel fabrication process is a dry process, only small amounts of contaminated liquid waste would be expected. One of the major features of this waste treatment system is the focus on solidifying waste for disposal. Contaminated liquids go through an evaporator for volume reduction and are then mixed with concrete and discharged in drums for disposal. Any solid wastes from the LWT system go to the MWT system for treatment and disposal. Any liquid wastes produced in the MWT system go back to the LWT system for treatment and concreted disposal.

Ideally, such a system would not produce any contaminated liquid wastes. However, small amounts of contaminated liquid wastes are shown in Table 7-4.2 to account for the disposal of some liquid wastes for practicality reasons to shorten the "internal recycle" for dealing with liquid wastes in the MWT and LWT systems.

The waste treatment process used for the generation of waste quantities distinguishes only between liquid and solid waste and between contaminated (and potentially contaminated) wastes and uncontaminated wastes. The classification of wastes (TRU and mixed TRU wastes, LLW and LLMW) is done after waste treatment, not before. However, considering the very low plutonium concentrations required for a waste classification as TRU waste (greater than 0.5 microgram of plutonium per gram of waste), whatever has been in direct contact with plutonium is most likely TRU waste. Table 7-4.1 summarizes waste origins for the different waste classes.

The waste volumes shown in Table 7-4.2 were obtained for the waste treatment process described in section 4.9. If another waste treatment process had been selected for the wastes generated in a dry MOX fuel fabrication process, different waste volumes could be obtained. The major differences, however, would be expected in the split between solid and liquid contaminated wastes.

Because a reference waste treatment process has not been selected yet for the Reference MOX FFF with a throughput of 100 MT of MOX fuel per year, most of the waste data in Table 7-4.2 is conservatively based on a much larger 150 MT-MOX FFF that Westinghouse has described in some detail in Ref. 7-2.

It should be noted that the GESMO plant of 1973 as well as the waste treatment descriptions in the other reports cited above are all based on a Westinghouse design with varying levels of modifications.

Table 7-4.1 shows the different waste classes, where the respective wastes originated, and how they will be disposed of.

Table 7-4.2 shows the quantities of waste in the different waste classes.

Table 7-4.1. Waste Origin Description and Method of Disposal

Waste Class	Waste Origin	Disposal
TRU waste	HEPA filters, process waste, 0.5% dirty scrap	Transferred to DOE for disposal
Mixed TRU waste	Solvents containing Pu scintillation vials	Transferred to DOE for disposal
Low-level waste	Any radioactive waste with less than 100 nCi plutonium per gram waste	Transferred to DOE for disposal
Mixed low-level waste	LLW combined with hazardous waste, solvents, scintillation vials	Transferred to DOE for disposal
Hazardous waste	Oil, lubricants, solvents, lead packing, batteries, soiled swipes, paint, hydraulic fluids, antifreeze solutions, film processing liquids	RCRA authorized disposal site
Nonhazardous waste (sanitary)	Nonradioactive, nonhazardous sanitary water, and discharges from lab sinks, floor washings	Sanitary drain
Other nonhazardous waste	Solid industrial waste, trash, storm water	Landfill

Table 7-4.2. Estimated Waste Generated During MOX FFF Operation

Waste Category	Annual Volume	Total Estimated Volume
Transuranic waste		
solid, m^3 (ft^3)	41.5 (1,465)	415 (14,650)
liquid, L (gal.)	0.4 (15)	4 (150)
Mixed transuranic waste		
solid, m^3 (ft^3)	4.67 (165)	46.7 (1,650)
liquid, L (gal.)	0.05 (1)	0.5 (10)
Low-level waste		
solid, m^3 (ft^3)	33.7 (1,190)	337 (11,190)
liquid, L (gal.)	0.3 (12)	3 (120)
Mixed low-level waste		
solid, m^3 (ft^3)	2.15 (76)	21.5 (760)
liquid, L (gal.)	0.02 (1)	0.22 (8)
Hazardous waste		
solid, m^3 (ft^3)	0.2 (7)	2 (70)
liquid, L (gal.)	1,000 (250)	10,000 (2,500)
Nonhazardous waste (Sanitary)		
solid, m^3 (ft^3)	1 (35)	10 (350)
liquid, million L (million gal.)		
sanitary water	17.223 (4.55)	172.2 (45.5)
process water	0.184 (0.0486)	1.84 (0.486)
blowdown	4.46 (1.179)	44.6 (11.79)
Total	21.867 (5.778)	218.67 (57.78)
Nonhazardous waste (other)		
solid, m^3 (ft^3)	150 (5,300)	1,500 (53,000)
liquid, L (gal.)	500 (130)	5,000 (1,300)

7.2.2. Air Emissions During Operation of the MOX FFF

Table 7-5 shows air emissions during operation of a MOX FFF. Gasoline emissions were determined in a fashion similar to that shown for coal in the following text, and are based on the resource estimates of Table 5.2.

Table 7-5. Air Emissions During Operation of a MOX FFF

Pollutant	Annual Emissions (kg)	Average Concentration (g/m^3)
Carbon Monoxide		
coal	1,625	0.31
gasoline	274.9	1.6
diesel	374.4	1.8
Oxides of Nitrogen (NO_x) [b]		
coal	4,452	0.82
gasoline	709.8	4.1
diesel	1738	8.1
Particulate Matter (PM-10)		
coal	215	0.04
gasoline	54.3	0.31
diesel	122.2	0.57
Oxide of Sulfur (SO_x)		
coal	24,700	4.15
gasoline	72.2	0.42
diesel	114.2	0.54
Volatile Organic Compounds		
coal	0	0
gasoline	56.2[a]	0.33
diesel	141.8	0.66
Hazardous Air Pollutants	insignificant	NA

Notes:
a. Hydrocarbon emissions
b. Gaseous releases of very small amounts of NO_x come from laboratory hoods. When released together with the air of the circulating system these amounts are well below the detection limits.

Air Emission Basis

OPERATING - Heating

	Degree Days (DD)	Fuel
Savannah River	2,497	650 MT coal (from Table 5-2)

650-MT coal is equivalent to 1.43×10^6 lb of coal.

Fuel Requirements:

SRS (heating)

Assumptions:

(1) Coal composition: $CH_{0.8}O_{0.08}N_{0.016}S_{0.008} \sim CH_{0.8}$

Actual annual emissions:

CO	(2.5 kg/MT coal)(650 MT coal) = 1,625 kg CO
NO_x	(6.85 kg/MT coal)(650 MT coal) = 4,452 kg NO_x
PM_{10}	(0.33 kg/MT coal)(650 MT coal) = 215 kg PM_{10}
SO_x	(38 kg/MT coal)(650 MT coal) = 24,700 kg SO_x

Composition for high volatile Bituminous coal (common eastern & western):

For 650 MT coal:
75 wt% carbon
5 wt% hydrogen
$0.75(650 \times 10^3 \text{ kg})(1 \text{ gmol}/0.012 \text{ kg}) = 4.0625 \times 10^7$ gmol C
$0.05(650 \times 10^3 \text{ kg})(1 \text{ gmol}/0.001 \text{ kg}) = 3.2500 \times 10^7$ gmol H

for 1 MT coal ~ 0.75(1000 kg)(1 gmol C/0.012 kg) = 62,500 gmol C
~ (0.05(1000 kg))(1gmol C/0.001 kg) = 50,000 gmol H

Per EPA-42:

Moles of CO,

2.5 kg CO/MT coal = 2.5 kg(1 gmol/0.028 kg) = 89 gmol CO/MT coal

Moles of CO_2,

(75,000 - 89) gmol CO_2 = 74,911 gmol CO_2/MT coal

Moles of NO_x,

6.85 kg NO_x/MT coal = 171 gmol NO_x/MT coal where x=1.67

Moles of SO_x,

38 kg SO_x/MT coal = 594 gmol SO_x/MT coal where x= 1.67

Overall Reaction:

$$CH_{0.8}+yO_2+\left(\frac{79}{21}\right)yN_2 = zCO+(1\text{-}z)CO_2+wSO_x+ 2nNO_x + \left[\left(\frac{79}{21}\right)y - n\right]N_2+0.4H_2O$$

Oxygen balance;

$2y=z+2(1-z)+xw+x(2n)+0.4$ where x~1.67 or 5/3 for NO_x + SO_x

$2y=z+2-2z+(5/3)w+(10/3)n+0.4$

$2y+z-(5/3)w-(10/3)n=2.4$

$3z-5w-10n+6y=7.2$

$$z = \left(\frac{89 \text{ gmole - CO/MT - coal}}{62,500 \text{ gmole - coal/MT - coal}}\right) = 0.001424 \text{ gmole - CO/gmole - coal}$$

$$2n = \left(\frac{171 \text{ gmole - NO}_x\text{/MT - coal}}{62,500 \text{ gmole - coal/MT - coal}}\right) = 0.002736 \text{ gmole - NO}_x\text{/gmole - coal}$$

n = 0.001363 gmol NO_x/gmol coal

$$w = \left(\frac{594 \text{ gmole - SO}_x\text{/MT - coal}}{62,500 \text{ gmole - coal/MT - coal}}\right) = 0.009504 \text{ gmole - SO}_x\text{/gmole - coal}$$

y = (1/6)[7.2-3(0.001424)+5(0.009504)+10(0.001363)] =

1.209480 gmol O_2/gmol coal

Overall Reaction:

$CH_{0.8}$+(1.209480)O_2+(4.520154)N_2 =

(0.001424)CO+(0.998576)CO_2+(0.009504)SO_x+(0.002736)NO_x+(4.518791)N_2+0.4H_2O

Total exhaust:

(0.001424+0.998576+0.009504+0.002736+4.518791+0.4) =

5.931031 gmol exhaust/gmol coal

(4.0625 x 10^7 gmol coal)(5.931031 gmol exhaust/gmol coal)(0.0224 m^3/gmol exhaust)

5.397×10^6 m^3/yr

Concentrations:

$$5.931031 \text{ gmole}\left(\frac{22.4 \text{ L}}{\text{gmole}}\right)\left(\frac{1 \text{ m}^3}{10^3 \text{ L}}\right) = 0.132855 \text{ m}^3$$

$$\left(\frac{0.001424 \text{ gmole - CO}}{0.132855 \text{ m}^3}\right)\left(\frac{29 \text{ g - CO}}{\text{gmole - CO}}\right) = 0.31 \text{ g CO/m}^3$$

$$\left(\frac{0.002736 \text{ gmole - NO}_x}{0.132855 \text{ m}^3}\right)\left(\frac{40 \text{ g - NO}_x}{\text{gmole - NO}_x}\right) = 0.82 \text{ g NO}_x\text{/m}^3$$

$$\left(\frac{0.009504 \text{ gmole - SO}_x}{0.132855 \text{ m}^3}\right)\left(\frac{58 \text{ g - SO}_x}{\text{gmole - SO}_x}\right) = 4.15 \text{ g SO}_x\text{/m}^3$$

$$\left(\frac{526{,}000 \text{ g - PM}_{10}}{13{,}200{,}000 \text{ m}^3}\right) = 0.040 \text{ g PM}_{10}\text{/m}^3$$

Stack Gas Velocity (heating)

Height = 38.1 m (dimensions provided by SAIC)
Diameter at exhaust = 3.01 m
Area at exhaust = 2.265 m^2

OPERATING - Diesel Fuel for Emergency Generators

SRS 24,000 L/yr

Actual annual emissions:

CO	(15.6 kg/1000 L)(24,000 L) = 374.4 kg CO (13,370 gmol)
NO_x	(72.4 kg/1000 L)(24,000 L) = 1738 kg NO_x (43,450 gmol)
PM_{10}	(5.09 kg/1000 L)(24,000 L) = 122.2 kg PM_{10}
SO_x	(4.76 kg/1000 L)(24,000 L) = 114.2 kg SO_x (1936 gmol)
VOC	(5.91 kg/1000 L)(24,000 L) = 141.8 kg VOC

Overall Reaction:

$$CH_{2.2}+yO_2+\left(\frac{79}{21}\right)yN_2 = zCO+(1-z)CO_2+wSO_x+2nNO_x+\left[\left(\frac{79}{21}\right)y-n\right]N_2+1.1H_2O$$

Oxygen balance:

$$2y=z+2(1-z)+xw+x(2n)+1.1 \qquad \text{where } x\sim1.67 \text{ or } 5/3 \text{ for } NO_x + SO_x$$

$$2y=z+2-2z+(5/3)w+(10/3)n+1.1$$

$$2y+z-(5/3)w-(10/3)n=3.1$$

$$3z-5w-10n+6y=9.3$$

Feed:

$$(700\text{ g/L - }CH_{2.2})(24,000\text{ L})\left(\frac{1\text{ gmole}}{14.2\text{ g}}\right)= 1.183\text{x}10^6\text{ gmol }CH_{2.2}$$

$$z=\left(\frac{13,370\text{ gmole - CO}}{1,183,000\text{ gmole - }CH_{2.2}}\right)=0.0113018\text{ gmole - CO/gmole - }CH_{2.2}$$

$$2n=\left(\frac{43,450\text{ gmole - }NO_x}{1,183,000\text{ gmole - }CH_{2.2}}\right)=0.0357287\text{ gmole - }NO_x\text{/gmole - }CH_{2.2}$$

$$n = 0.0178644\text{ gmol }NO_x\text{/gmol coal}$$

$$w=\left(\frac{1936\text{ gmole - }SO_x}{1,183,000\text{ gmole - }CH_{2.2}}\right)=$$

$$0.00163652\text{ gmole - }SO_x\text{/gmole - }CH_{2.2}$$

$$y = (1/6)[9.3-3(0.0113018)+5(0.00163652)+10(0.0178644)] =$$

$$1.575487\text{ gmol }O_2\text{/gmol }CH_{2.2}$$

Overall Reaction:

$CH_{2.2}$+(1.575487)O_2+(5.926832)N_2 =

(0.011301)CO+(0.988698)CO_2+(0.001636)SO_x+(0.035728)NO_x+(5.908968)N_2+1.1H_2O

Total exhaust:

(0.011301+0.988698+0.001636+0.035728+5.908968+1.1) =

8.046331 gmol exhaust/gmol fuel

$$\left(1.183\text{x}10^6 \text{ gmole - CH}_{2.2}\right)\left(\frac{8.046331 \text{ gmole - exhaust}}{\text{gmole - fuel}}\right)\left(\frac{0.0224 \text{ m}^3}{\text{gmole - exhaust}}\right)=$$

$2.1332\text{x}10^5$ m^3/yr

Concentrations:

$$\left(\frac{374,400 \text{ g - CO}}{213,320 \text{ m}^3}\right)=1.8 \text{ g CO/m}^3$$

$$\left(\frac{1,738,000 \text{ g - NO}_x}{213,320 \text{ m}^3}\right)=8.1 \text{ g NO}_x\text{/m}^3$$

$$\left(\frac{114,200 \text{ g - SO}_x}{213,320 \text{ m}^3}\right)=0.54 \text{ g SO}_x\text{/m}^3$$

$$\left(\frac{122,200 \text{ g - PM}_{10}}{213,320 \text{ m}^3}\right)= 0.57 \text{ g PM}_{10}\text{/m}^3$$

$$\left(\frac{141,800 \text{ g - VOC}}{213,320 \text{ m}^3}\right)=0.66 \text{ g VOC/m}^3$$

OPERATING - Diesel/Gasoline Fuel for Motor Vehicles

SRS 19,330 L/yr

Actual annual emissions:

CO (14.22 kg/1000 L)(19,330 L) = 274.9 kg CO (9818 gmol)

NO_x	(36.72 kg/1000 L)(19,330 L) = 709.8 kg NO_x (17,745 gmol)
PM_{10}	(2.809 kg/1000 L)(19,330 L) = 54.3 kg PM_{10}
SO_x	(3.735 kg/1000 L)(19,330 L) = 72.2 kg SO_x (1224 gmol)
HC	(2.906 kg/1000 L)(19,330 L) = 56.2 kg HC

Overall Reaction:

$$CH_{2.2}+yO_2+\left(\frac{79}{21}\right)yN_2 = zCO+(1-z)CO_2+wSO_x+ 2nNO_x + \left[\left(\frac{79}{21}\right)y - n\right]N_2+1.1H_2O$$

Oxygen balance:

$2y=z+2(1-z)+xw+x(2n)+1.1$ where $x\sim 1.67$ or 5/3 for $NO_x + SO_x$

$2y=z+2-2z+(5/3)w+(10/3)n+1.1$

$2y+z-(5/3)w-(10/3)n=3.1$

$3z-5w-10n+6y=9.3$

Feed:

$$(700\ \text{g/L - }CH_{2.2})(19,330\ \text{L})\left(\frac{1\ \text{gmole}}{14.2\ \text{g}}\right) = 9.5289\text{x}10^5\ \text{gmol}\ CH_{2.2}$$

$$z = \left(\frac{9818\ \text{gmole - CO}}{952,890\ \text{gmole - }CH_{2.2}}\right) = 0.010303\ \text{gmole - CO/gmole - }CH_{2.2}$$

$$2n = \left(\frac{17,745\ \text{gmole - }NO_x}{952,890\ \text{gmole - }CH_{2.2}}\right) = 0.018622\ \text{gmole - }NO_x\text{/gmole - }CH_{2.2}$$

$n = 0.009311$ gmol NO_x/gmol coal

$$w = \left(\frac{1224\ \text{gmole - }SO_x}{952,890\ \text{gmole - }CH_{2.2}}\right) =$$

$$0.001285\ \text{gmole - }SO_x\text{/gmole - }CH_{2.2}$$

$y = (1/6)[9.3-3(0.010303)+5(0.001285)+10(0.009311)] =$

$$1.561438\ \text{gmol}\ O_2\text{/gmol}\ CH_{2.2}$$

Overall Reaction:

$CH_{2.2}$+(1.561438)O_2+(5.873980)N_2 =

(0.010303)CO+(0.989697)CO_2+(0.001285)SO_x+(0.018622)NO_x+(5.964467)N_2+1.1H_2O

Total exhaust:

(0.010303+0.989697+0.001285+0.018622+5.964467+1.1) =

8.084374 gmol exhaust/gmol fuel

$$(952{,}890 \text{ gmole - } CH_{2.2})\left(\frac{8.084374 \text{ gmole - exhaust}}{\text{gmole - fuel}}\right)\left(\frac{0.0224 \text{ m}^3}{\text{gmole - exhaust}}\right)=$$

172,560 m^3/yr

Concentrations:

$$\left(\frac{274{,}900 \text{ g - CO}}{172{,}560 \text{ m}^3}\right) = 1.6 \text{ g CO/m}^3$$

$$\left(\frac{709{,}800 \text{ g - NO}_x}{172{,}560 \text{ m}^3}\right) = 4.1 \text{ g NO}_x\text{/m}^3$$

$$\left(\frac{72{,}200 \text{ g - SO}_x}{172{,}560 \text{ m}^3}\right) = 0.42 \text{ g SO}_x\text{/m}^3$$

$$\left(\frac{54{,}300 \text{ g - PM}_{10}}{172{,}560 \text{ m}^3}\right) = 0.31 \text{ g PM}_{10}\text{/m}^3$$

$$\left(\frac{56{,}200 \text{ g - HC}}{172{,}560 \text{ m}^3}\right) = 0.33 \text{ g HC/m}^3$$

7.2.3. Radioactive Releases during Operation of the MOX FFF

7.2.3.1. Fuel Activities. In calculating the activities of radioactive releases, only the plutonium and americium isotopes were considered. Although there is approximately 20 times as much uranium present in MOX fuel as plutonium and americium, the uranium-235 and -238 half lives are 7.1 x 10^8 yr and 4.51 x 10^9 yr, rendering their contributions to the releases negligible, as illustrated below.

Table 7-5.1. Contributions to Releases

ISOTOPE	HALF-LIFE (yr)	ACTIVITY (Ci/g)
U-235	710,000,000	0.000002
U-238	4,510,000,000	0.0000003
Pu-238	86	17.5
Pu-239	24,400	0.0616
Pu-240	6,580	0.227
Pu-241	13.2	113
Pu-242	380,000	0.00391
Am-241	458	3.25

The activity data in Ci/g for weapons plutonium are based on the following conversions:

Table 7-5.2. Activity Data Conversions for Weapons Plutonium

Isotope	Mass Ratio	Activity (Ci/g)	Contribution (Ci/g Pu)	Contribution (micro-Ci per 0.6 mg Pu)[a]
Pu-238	0.0003	17.5	0.0053	3.1870
Pu-239	0.9328	0.0616	0.057	34.477
Pu-240	0.06536	0.227	0.015	8.9018
Pu-241	0.0005	113	0.057	34.298
Pu-242	0.001	0.00391	0.000004	0.00237
Total Pu	1.000		0.135	
Am-241	0.001	3.25	0.00325	1.95

Note: a. A release of 0.6 mg of Pu has been assumed as described in Section 7.2.3.2. Plutonium isotopics have been provided to LANL by DOE MD and SAIC and have been normalized to 100%.

The data listed under Contribution (Ci/g) are for 1 g of pure weapons plutonium (i.e., without americium) and show the contributions of the different plutonium isotopes. The data listed for Am-241 are for 1 mg of Am-241.

Assuming an Am-241 concentration of 0.9% in weapons-grade plutonium of, the above-stated concentrations change slightly and the activity contributions for an annual releases of 0.6 mg of plutonium are as follows:

Table 7-5.3. Activity Concentrations for Annual Releases of Plutonium				
Isotope	**Content**	**Contribution, Micro-Curie Per 0.6 g Pu/Am**	**Decay Mode**	**Ci/g Fuel**
Pu-238	0.0003	3.158	alpha	0.00526
Pu-239	0.9244	34.17	alpha	0.05694
Pu-240	0.0647	8.821	alpha	0.01470
Pu-241	0.0005	33.99	beta	0.05665
Pu-242	0.0010	0.002	alpha	0.000004
Am-241	0.0090	17.60	alpha	0.02932
Total Pu/Am	1.000	97.73	alpha + beta	0.163
Plutonium and Americium isotopics were provided to LANL by DOE MD and SAIC and have been normalized to 100%.				

This yields the following activities per gram of fuel:

0.163 Ci (alpha + beta)/g
0.106 Ci (alpha)/g
0.057 Ci (beta)/g

where the beta activity comes solely from Pu-241 decays and the alpha activity from the other isotopes.

For an airborne release of 0.6 mg of Pu/Am fuel the following activities were obtained:

97.7 microcurie (alpha + beta)
34.0 microcurie (beta only)
63.7 microcurie (alpha only)

7.2.3.2. Underlying Database. An annual release of not more than 0.6 mg/yr of plutonium has been estimated. Following is a discussion of the basis for this data.

The Environmental report for the Westinghouse Recycle Fuels Plant ER-W (Ref. 7-3) bases its assessment of radioactive airborne reactivity on the use of recycle plutonium with the following composition:

Pu-238	0.091%
Pu-239	78.009%
Pu-240	16.369%
Pu-241	3.058%
Pu-242	0.473%

Using the Ci/g data from above yields the following activity for recycle plutonium:

alpha + beta activity: 3.557 Ci/g

of which 3.45 Ci/g come from the beta decay of Pu-241.

The maximum expected release of plutonium activity to the atmosphere through the ventilation system is based on experience and data obtained at the Westinghouse Plutonium Fuel Development Laboratory at Cheswick, Pennsylvania. These data were collected by five ventilation stack monitors that continuously monitored the concentration of alpha activity past the final HEPA filter in each duct that exhausts air before releasing it to the atmosphere.

Based on those data, it was concluded that the annual average concentration of plutonium discharged to the atmosphere was equal to or less than the minimum detectable level of alpha activity of 5.4×10^{-15} microcurie/cc. With a flow rate of 32,000 cfm, a source strength of 4.0×10^{-6} microcurie/sec (alpha only) was obtained, and the beta source strength (due entirely to Pu-241) of 1.4×10^{-5} microcurie/sec was calculated. The beta activity is obtained by multiplying the alpha activity by 34, yielding 136×10^{-6} microcurie/sec. The total source strength (alpha + beta) per year was calculated to 4,290 microcurie/year or 4.29 mCi/yr. Using the total activity for this recycle plutonium of 3.557 Ci/g yields a plutonium release of 1.2 mg/yr.

Using these data for the release from a 200-MT MOX FFF to extrapolate the data for a 100-MT MOX FFF, a value of 0.6 mg/yr for the 100-MT MOX FFF was assumed.

Note: There are various other release estimates in the literature whose basis could not be validated. The GESMO (Ref. 7-4) assumes a release fraction of 10^{-9}, which would yield a release of 3.5 mg plutonium per year. A PNNL investigation (Ref. 7-5) based airborne releases on a daily release fraction of 1.5×10^{-11}, which would result in an annual release fraction of 5.5×10^{-9}; applying these data to the new MOX FFF would result in an annual release of 19 mg of plutonium.

An investigation at BNWL in 1973 (Ref. 7-6) showed no correlation between MOX fuel throughput of a plant and airborne releases. A 5 microgram/yr release had been recommended. This release is substantially lower than the data used here.

The data based on the Westinghouse Environmental Report (Ref. 7-3) shown in Table 7-6 were given preference because they have an experimental basis albeit of a very conservative nature. The conservatism comes from the fact that no release had been measured at Westinghouse's Cheswick plant, and a release was then postulated that was equal to the sensitivity of the measuring devices, i.e., the minimum detectable levels.

Note: The airborne releases are controlled by the HVAC system with its HEPA filter banks. Proper prefiltering and assurance that the fuel powder particle size distribution is well above the transmission probability for the filters will result in very low radionuclide releases.

In addition, HEPA filter efficiency and reliability has substantially increased since the measurements at the Cheswick plant were conducted (starting in mid-1969 and continuing for four years).

The estimated radioactive releases during operation of the new MOX FFF are listed in Table 7-6.

TABLE 7-6.
Radioactive Releases During Operation of the New MOX FFF

1. Average release height[a]		8 m (25 ft)	
2. Release to air			
Isotope	Weight % By Isotope[b]	Release Micro-Ci/Yr	Decay Mode
Pu-238	0.0003	3.158	alpha
Pu-239	0.9244	34.17	alpha
Pu-240	0.0647	8.821	alpha
Pu-241	0.0005	33.99	beta
Pu-242	0.001	0.002	alpha
Am-241	0.0090	17.60	alpha
U235	~0.0 to 0.025	0 - see text (7.2.5.1)	alpha
U-238	0.992745	0 - see text (7.2.5.1)	alpha
For the release of 0.6 mg/yr of Pu/Am fuel, the following activities were obtained: **97.7 microcurie/yr (alpha + beta)** **34.0 microcurie/yr (beta only)** **63.7 microcurie/yr (alpha only)**			
3. Release to surface water - none			

Notes:

a. The stack height is assumed to be the HVAC discharge point, slightly above the roof of the MOX FFF. The heating furnace (natural gas) stack discharge is assumed to be at approximately the same height (slightly above the roof of the MOX FFF) or about 8 m.

b. Plutonium and Americium isotopics were provided to LANL by DOE MD and SAIC and have been normalized to 100%.

7.3. References

7-1. American Institute of Architects, Architectural Graphics Standards, 8th ed., J. Wiley & Sons, NY, NY 1988.

7-2. Westinghouse Plutonium Disposition Study of 1994 prepared for DOE.

7-3. "Environmental Report, Westinghouse Recycle Fuels Plant", prepared for the NRC in 1973, Docket Number 70-14323.

7-4. "Final Generic Environmental Statement on the Use of Recycle Plutonium in Mixed Oxide Fuel in Light Water Reactors", NUREG-0002, 1973).

7-5. "Description of Reference LWR Facilities for Analysis of Nuclear Fuel Cycle" by K. J. Schneider and T. J. Kabele, PNL-2286 (1979).

7-6. "Considerations in the Assessment of the Consequences of Effluents from Mixed Oxide Fuel Fabrication Plants," by J. M. Selby, E. C. Watson et al., BNWL-1697 (June 1973).

8. MOX FUEL FABRICATION ACCIDENTS ANALYSIS

8.1. Introduction

Mixed oxide fuel fabrication facilities are required to be designed, fabricated, constructed, tested and operated under a rigid quality assurance program. Quality assurance includes all those planned and systematic actions necessary to provide adequate confidence that structures, systems, and components (SSCs) and operation programs will perform satisfactorily in service.

All operations at MOX fabrication facilities that involve handling plutonium, except when it is contained in shipping containers or sealed fuel rods, are carried out within shielded process enclosures such as gloveboxes. These enclosures confine plutonium during normal operations and in the event of equipment failure. In addition, the process building will be designed so that all exhausted emissions from the process pass through multiple stages of HEPA filtration system. The process building's essential equipment and supporting systems are designed to withstand impacts due to natural phenomena related to tornadoes, earthquakes, and floods.

During the life of the MOX FFF, some equipment failures may occur. Monitors are installed to detect such failures or process-upset conditions that can cause safety-related damage. Corrective action is automatically provided. The ventilation system is designed to function during normal, abnormal and severe accident conditions so that all plant ventilation air through two stages of high efficiency particulate air (HEPA) filters before it is released to the environment. The referenced MOX FFF plant will be

- designed, fabricated, constructed, tested, and operated according to applicable regulatory requirements;
- designed to cope with and minimize the likelihood of potential accidents; and
- designed to minimize the off-site consequences for potential accidents.

A wide spectrum of accidents for fuel fabrication facilities both in terms of frequency and consequences has been identified. Some minor operational incidents are expected to occur as part of normal operation. More serious accidents such as a glovebox window breakage are less likely to occur, although the off-site consequences from such events are bounded by the design basis accidents (DBAs).

8.2. Design Basis Accidents

The design basis accidents that may occur include criticality, explosion, fire, or seismic event. These upper-limit accidents are analyzed to identify potential releases and their effect on the environment. These design basis accidents are not expected to occur during the service life of the facility and have an estimated frequencies of occurrence 1.0E-04 to 1.0E-06/yr. The postulated DBAs, as well as Beyond Design Basis Accidents (BDBAs), are described below.

8.2.1. Criticality. Nuclear criticality safety is a major consideration in the MOX FFF and in equipment design, development of operating procedures, and the regulatory review and approval process. All operations will be designed and performed to comply with the double contingency principle, i.e., at least two unlikely, independent failures must occur before a nuclear criticality is physically possible. To the extent practicable, the equipment will be designed to preclude the likelihood of nuclear criticality. In addition, strict administrative controls will be applied during all modes of operation. A criticality safety program will also be implemented that will ensure that the design safety features and administrative controls are effectively carried out during all modes of facility operation.

There have been no criticality accidents to date in the process operations involving dry materials. Only a few accidental criticalities have occurred in process operations involving aqueous or moderated systems. The reference MOX FFF will use dry powder, and neutron moderators will be severely limited and controlled in the MOX fuel fabrication process.

Although no significant environmental consequences have resulted from this type of accident, the environmental effect of nuclear excursion in a MOX FFF is examined.

For the postulated criticality accident, it is assumed that all noble gases such as krypton, xenon and 25% of the iodine formed by the fission would be released from the material. It is also assumed that the criticality occurs inside a glovebox. The impact of the postulated criticality accident would not threaten integrity or performance of the building ventilation filtration system, so that any potential releases to the environment would be filtered before release to the environment.

Frequency

The frequency of a criticality excursion from a proposed, early 1970's, MOX fabrication facility was estimated to be 8.6E-03/yr, based on the historical criticality accident frequency for all types of research, weapon, and processing facilities (Ref. 8-1). Since that time, the safety engineering features and administrative controls to preclude criticality accidents have been significantly improved in all nuclear facilities. Design criteria such as safe geometries, coordinated facility equipment arrangements and operational administrative controls to preclude criticality will be incorporated into the design and operation of the proposed MOX facility. In addition, the frequency for criticality reported in Ref. 8-1 was based on the criticality frequency for processes involving solutions in unsafe conditions, not in an oxide powder process proposed for the MOX FFF. The powder process does not use a neutron moderating material and thus the likelihood of a criticality accident is much lower. These differences result in an estimated reduction in the frequency of accidental criticality of at least two orders of magnitude.

Therefore, the frequency of a criticality accident in the proposed MOX FFF is estimated to be in the range of 1.0E-04 to 1.0E-06/yr, which is considered to be extremely unlikely.

Source Term

The number of fissions that would take place during an accidental criticality have been estimated to be 10E+19 in Ref. 8-2. Because the entire glovebox inventory could be involved, a damage ratio of 1.0 was used for conservatism. In appendix B, Table B-10 *shows the source term for this event, and the characteristics for the Airborne Release* Fraction (ARF) and Respirable Fraction (RF) were obtained from Ref. 8-3.

8.2.2. Explosion in Sintering Furnace. Several types of explosions can be postulated in the MOX FFF. The most common explosions examined are those in the sintering/reduction furnaces. An explosion is possible in these furnaces because even though the furnace uses a nonexplosive mixture of 6% hydrogen and 94% argon or nitrogen (also supplied to the clean scrap recovery operations), a malfunction may occur. It is postulated that the gas mixture control system malfunctions allowing an explosive mixture of hydrogen and oxygen gas to accumulate in the sintering furnace. Such an explosion would be highly localized and would probably result in damage only to a small area of the furnace and adjacent gloveboxes. In contrast, no credible explosion mechanism has been identified which would affect the entire facility or result in major facility-wide damage.

For analytical purposes, a bounding explosion/deflagration is postulated to occur in one of the sintering furnaces in the fuel fabrication building. An explosion in other facility areas such as the clean scrap recovery furnace is not expected to result in a higher source term because of the lesser quantities of materials involved. The initiators for the postulated explosion/deflagration are assumed to be multiple equipment failures and operator errors that would lead to a buildup of hydrogen and inflow of oxygen in the inert furnace atmosphere. An ignition source is assumed to be present, and an explosion occurs.

The explosion would probably be directed out at both ends of the furnace and into the loading and unloading gloveboxes at either end of the furnace. The gloveboxes could be breached, and the pellets and possibly a small amount of mixed oxide fines could be spread around the room. It is not expected that significant quantities of plutonium particles in the respirable range from damage to the pellets or dispersion of the fines will be produced. It is also assumed that two stages of HEPA filters will remain intact, because of their distance from the explosion.

Such an explosion in a pellet sintering furnace would have a limited amount of energy. Therefore, the damage that could result from this type of event would have limited consequences. The furnaces are also assumed to be separated and isolated from each other so that they are not affected by the explosion. It is assumed that the furnace contains about 25 boats (i.e., trays) of MOX pellets. In addition, it is assumed that the feed loading and the product unloading gloveboxes contain 25 boats of MOX pellets each.

Frequency

The frequency of an explosion in the sintering furnace of the proposed MOX FFF was estimated to be 5.0E-02/yr based on Ref. 8-1. However, an explosion in the proposed MOX FFF is considered to be unlikely, that is, in the range of 1.0E-04 to 1.0E-06/yr. This is due to design features such as inert atmosphere blanket gas, a hydrogen detection system, off-gas control system and the operating administrative controls that will be incorporated into the facility operations.

Source Term

It is assumed that at the time of the postulated event, 25 boats with approximately 900 green pellets, each containing 5 g of MOX are in the loading glovebox awaiting sintering, 25 boats are in the furnace, and 25 boats of sintered pellets are in the output glovebox. The green pellets are assumed to be the most vulnerable for release under accident conditions. The largest release would be expected if air leaked into the loading glovebox and resulted in a hydrogen deflagration. Hydrogen concentrations in the nitrogen or argon/hydrogen blanket gas are expected to be near or below the lower flammable and explosive limits for hydrogen/air mixtures, so it would be prohibitive to have a large quantity of hydrogen and air at an explosive concentration level.

It is conservatively assumed that a deflagration occurs in the loading glovebox that subjects all of the green pellets to the explosive shock. There are no direct data for identifying the fraction of the pellets that would become airborne and respirable under these conditions. According to Ref. 8-3, as an upper limit, if the material were simply unpressed MOX powder, as much as 10% of the material subjected to the deflagration forces might become airborne and 70% of that might become respirable. As mechanically compacted green pellets, the estimated fraction is at least an order of magnitude lower. Reference 8-3 suggests that UO_2 pellets subjected to energy densities comparable to 30 m/s impact would have from 0.01% to 0.1% of the pellets released in a respirable form. The airborne release fraction for green pellets subjected to a glovebox hydrogen deflagration is assumed to be approximately 10 times higher than sintered pellets, or about 1.0% with 100% of that respirable. The source term for this accident is shown in Appendix B, Table B-18.

8.2.3. Design-Basis Fire in the Pellet Processing Area. A design-basis fire in the pellet processing area is postulated to occur and has been selected as a bounding accident scenario for the potential fires within the MOX fuel fabrication facility. The processing area is assumed to contain MOX powder and combustible materials within the area. The facility will be designed to reduce the possibility of fire to a minimum. Fireproof and fire-resistant building materials will be used, fire detection and fire suppression equipment will be installed, and the fabrication process will be chosen with consideration for reducing the fire potential in the facility.

It is assumed that the postulated design-basis fire would involve all the hydraulic fluid, lubricants, and other combustibles within the pellet pressing area, and in the case of hydraulic fluid, non-fireproof material were used. Programmatically, this could not occur, because combustibles will be restricted and maintained to a minimum under the fire protection program. However, it is assumed that if a hydraulic fluid line is ruptured, the hydraulic fluid would ignite because of contact with hot surfaces. It is assumed that the fire would engulf the pellet processing area and burn the MOX materials in the pelleting press and the feed hopper. It is also assumed that the building HEPA filters would remain intact since they would be protected by spray systems to cool the unfiltered gas and prevent loss of integrity of the filters.

Frequency

The frequency of a design basis fire in the MOX FFF was estimated to be 1.0E-05/yr based on fuel fabrication failure data from Ref. 8-1. A major fire in a modern MOX FFF is considered to be extremely unlikely, in the range of 1.0E-04 to 1.0E-06/yr. This is because of such design features as detection and suppression, fire barriers, and the use of non flammable materials in the process and the strict combustible control program that will be incorporated in the facility operations.

Source Term

At the time of the event, it is assumed that fire will occur in the MOX pellet processing press. The fire is assumed to involve the material in the pelleting press and the feed hopper, which is in the form of MOX powder. Because the entire blending area inventory would be involved, a damage ratio of 1.0 is used. Appendix B, Table B-19 shows the source term for this event and lists the values for the ARF and RF obtained from Ref. 8-3.

8.2.4. Design Basis Earthquake. A DBE is postulated to occur and has been selected as the bounding design basis event for all the other natural phenomena hazards (NPH). The MOX FFF will be designed to withstand the effects of the postulated design-basis NPH events. Appropriate seismic structural design loading, seismic qualification, wind, flood loading, etc. will be incorporated into the design of the facility so that the building confinement, including ventilation and filtration, will remain functional during and after a design-basis event. However, in a design-basis earthquake, some nonseismically qualified process equipment may fail, and some process material might spill. It is necessary to note that NPH design-basis loads are site specific, i.e., the magnitude of DBE to which the MOX facility will be designed will depend on the specific seismicity level designated for that site. Each potential MOX site will have its own applicable criteria for design and operation.

It is assumed that a seismic event with a magnitude of Category I will cause the failure of equipment and processes. The damage is assumed to occur in the following areas of the process: the powder blending and compaction of unsintered pellets, the boat loading, green pellet storage, and sintering processes. Scrap material is also considered to be vulnerable to a seismically induced spill. Sintered pellets and loaded fuel rods are considered to be an insignificant contributor to the overall source term because of their physical material form. Material in 3013 cans would be adequately protected from seismic effects. In addition, it is assumed that because of the large quantities of MOX material in the hopper and bulk storage, equipment will be designed to be sufficiently robust to withstand the DBE. Finally, it is conservatively assumed that the glovebox filtration will fail.

Frequency

The frequency of this event is estimated to be 5.0E-4/yr, as defined in DOE-STD-1020 (Ref. 8-4).

Source Term

The source term for the design DBE scenario is based on the assumed response of the building inventory to seismic loads. The following assumptions were made:

- Material in 3013 cans in the receiving and storage areas is protected from release because of the robustness of the design, for a damage ratio of 0.0;
- Material in the hopper storage area is protected from release becasue of the robustness of the hopper vessel.
- Material in the powder blending and compaction areas is subject to free-fall spill of powder, for an ARF of 2.0E-3 and an RF of 0.3 (Ref. 8-3).
- Material in the granulating, pelleting, boat loading, green pellet storage, and sintering areas is subject to impaction stress on aggregate material, for a combined ARF/RF of 2.1E-5 (Ref. 8-3). This value is based on an empierical correlation between ARF/RF and energy density, requireing estimation of specimen density and fall height. For this analysis, specimen density is taken to be 10.96 g/cm^3, based on the density of the compacted UO_2 pellets used in the underlying experiments. Fall height is taken to be 1 m, which approximates the distance from the gloveboxes to the floor.
- Material in the areas of sintered pellet storage, pellet grinding and storage, fuel rod loading and storage, and fuel shipment loading is assumed to contribute insignificantly to the source term, becasue of the material form.
- Material in the clean scrap recovery, dirty scrap, and analytical areas is assumed to be 50% powder and 50% aggregate, for ARF/RF values of 1.0E-3/0.3 and 2.1E-5, respectively, as described above.

In Appendix B, Table B-20 shows the source term for this event and lists the values for the material at risk, damage ratio, airborne release fraction, respirable fraction, and leak path factor obtained from Ref. 8-3.

8.3. Beyond-Design-Basis Accidents

Two beyond-design-basis accidents were postulated that would bound a range of low-probability accidents with frequencies as low as 1.0E-07/yr and are considered to be beyond extremely unlikely during the life cycle of the facility. A major facility fire with total failures of major fire protection systems such as detection, suppression, and fire barriers is postulated to occur and is considered to bound facility process related operational accidents. Also, a beyond-design-basis earthquake that results in total collapse of the facility's structures is postulated to occur and is considered to bound the natural-phenomena-initiated accidents.

8.3.1. Beyond-Design-Basis Fire

It would require a major accident to breach facility confinement and release unfiltered plutonium to the environment. There are few accidents in a facility major event that can theoretically produce damage of sufficient magnitude to compromise the final confinement barriers. Specifically the facility will, as a minimum, be structurally designed and built to satisfy criteria relative to earthquake and tornadoes. However, finite possibilities exist that the facility could be stressed by forces beyond those used for design. Major facility fires also seem incredible in the fuel fabrication buildings where combustibles are limited, but experience indicates that they can occur. In summary, major plant accidents that can cause major facility damage are not incredible but are beyond extremely unlikely. This is because no large amounts of combustible materials are expected to be used in the fuel fabrication process or the glove boxes; the restricted access operational area will be constructed of noncombustible materials, and adequate fire-detection and suppression systems will typically be provided for this type of operation. In addition, to minimize any possibility of plutonium release if a fire should occur, the final filtration system will be physically isolated, and the filters will be protected by design safety features to ensure their integrity and functionality.

The bulk of plutonium in the facility will be stored in a hardened area such as a vault. A plant fire that could cause catastrophic breaching of the final barrier is not conceivable with the expected concrete construction of the facility, the low combustible material loading, and the expected airtight nature. Because of these factors a total burning is considered incredible. For the postulated event, the structure (final barrier) was assumed to remain intact after a facility fire.

A fire in the blending process is postulated as the beyond-design basis fire for the MOX FFF. The blending process was selected because of the relatively large amount of plutonium that could potentially become involved in a fire. However, there is normally a lack of sufficient combustible material in the blending process to support a fire; therefore, the beyond-design-basis fire simply assumes that combustible material has been introduced by unspecified means into the blending process. Material in vault storage in 3013 cans was not considered for the beyond-design-basis fire, because no reasonable means of breaching the cans (i.e., the containment) could be postulated. At the time of an accident, it is assumed that one batch of MOX blend would be in the blender.

The MOX FFF is designed to filter particulates from building exhaust before release to the atmosphere. It is expected that the building HEPA system will be designed to withstand reasonably foreseeable fire loading and to provide filtration to building releases from fire. In order to bound the potential consequences of a fire at the MOX facility, it is assumed that the beyond-design-basis fire is of sufficient magnitude to fail the building ventilation and filtration system, possibly because of plugging the HEPA filters with smoke/ash from a fire.

Frequency

The frequency of major facility fire is estimated to be as low as 1E-07/yr based on fuel fabrication failure data from Ref. 8-1, although a major fire in a modern FFF is beyond extremely unlikely. The conditional probability that the building ventilation system could also fail as a result of the fire is estimated to be less than 0.1.

Source Term

At the time of the event, it is assumed that fire will occur in the MOX blending process gloveboxes, which will involve the blender containing plutonium and depleted uranium powder. A total of 225 kg of MOX powder is assumed to be at risk. Based on Ref. 8-3, an ARF of 6E-03, RF of 1E-02, a damage ratio of 1.0 and leak path factor of 1.4E-02 are assumed. The beyond-design-basis fire is assumed to be of such a magnitude that the ventilation system fails. Some material is assumed to leak to the outside. In Appendix B, Table B-21 shows the source term for this event and lists the LPF, DR, ARF, and RF.

8.3.2. Beyond-Design-Basis Earthquake. In order to bound the consequences of potential accidents at the MOX FFF, a facility total collapse scenario is postulated as a beyond-deign-basis event. Scenarios causing this level of catastrophic damage cannot be ruled out, if only for the fact that at frequencies as low as 1E-6 to 1E-7/yr, it is not possible to conclusively demonstrate survival of facility structures against seismic phenomena. Thus, the facility total collapse scenario is an artificial, surrogate scenario that is not tied to any specific frequency, nor to any specific initiating event. It represents a level of facility damage that is responsing to forces far beyond the design basis, but which cannot be ruled out of the realm of possibility.

In the total collapse scenario, it is assumed that the roof, main floor, and walls collapse inward into the footprint of the building and onto the basement floor. All building confinement is assumed to be lost. Material in the receiving and storage areas is assumed to be protected from phenomena associated with the event, based on use of the 3013 cans, which are double walled and specifically designed to provide protection against impaction stress. Materials in process and out of 3013 cans are assumed to be impacted by the falling debris. A damage ratio of 1.0 is used for this material. Airborne release fractions and respirable fractions were obtained from Ref. 8-3. The LPF through the building rubble could vary from less than 0.1 to near 1.0. To be conservative, a LPF of 1.0 is assumed.

The MOX FFF is equipped with a water fire protection system, and in the event of facility collapse it is assumed that sprinkler pipes will fail and that water will be available to act as a neutron moderator. Therefore, a criticality is also assumed to occur, of a magnitude identical to that identified in Section 8.2.1.

Frequency

The frequency for this event is estimated to be as low as 1.0E-07/yr.

Source Term

The source term for the total collapse scenario is based on the assumed response of the building inventory to the impaction stresses from falling debris. The following analytical assumptions were made:

- Material in 3013 cans in the receiving and storage areas is protected from release because of the robustness of the design, for a damage ratio of 0.0.
- Material in the hopper storage, powder blending, and compaction areas is subject to large falling object impaction stress on powder, for an ARF of 1E-3 and an RF of 0.3 (Ref. 8-3).
- Material in the granulating, pelleting, boat loading, green pellet storage, sintering and storage, pellet grinding and storage, and fuel rod loading areas is subject to impaction stress on aggregate material, for a combined ARF/RF of 8.6E-5 (Ref. 8-3). This value is based on an empirical correlation between ARF/RF and energy density and requires estimation of specimen density and fall height. For this analysis, specimen density is taken to be 10.96 g/cm^3, based on the density of the compacted UO_2 pellets used in the underlying experiments. Fall height is taken to be 4 m, which approximates the distance from the first-floor gloveboxes to the basement floor.
- Material in the clean scrap recovery, dirty scrap, and analytical areas is assumed to be 50% powder and 50% aggregate, for ARF/RF values of 1E-3/0.3 and 8.6E-5, respectively.

In Appendix B, Table B-22 shows the source term by process, and lists the values of material at risk (MAR), DR, ARF, RF, and LPF used in the analysis. In addition, the total collapse scenario may result in the criticality source term presented in Appendix B, Table B-10.

8.4. Accident Consideration of Toxic Chemicals

A few toxic chemicals are used in the fuel fabrication process. These are the usual industrial chemicals for which standard safe-handling procedures would greatly limit the potential for accidental release. As part of the EIS process, the impact of accidents involving these materials on the environment will be addressed. The chemicals identified that may be of concern are listed in Table B-14.

8.5. Accident Sequence/Appendix B Relationship

Developing the accident sequences described in section 8 is the second step in accident analysis process, which inputs to the third step, which is the consequence estimates. The source term for each type of postulated accident (DBAs or BDBAs) has been developed and is provided in Appendix B. Appendix B provides the accident analysis process logic, the assumptions, the input data, and the source terms for postulated accidents judged to be bounding for EIS accident evaluations.

8.6. References

8-1. BNWL-1697, "Considerations in Assessment of Consequences of Effluents from Mixed Oxides Fuel Fabrication Plants," Revision 1, , June 1975.

8-2. Regulatory Guide 3.35, "Assumptions Used for Evaluating the Potential Radiological Consequences of Accidental Nuclear Criticality, in a Plutonium Processing and Fuel Fabrication Plant," US Nuclear Regulatory Commission, Washington, DC, May 1977.

8-3. DOE-HDBK3010-94, "Airborne Release Fractions/Rates and Respirable Fractions forNonreactor Nuclear Facilities," 1994.

8-4. US DOE Std-1020-94, "Natural Phenomena Hazards Design and Evaluation Criteria for Dept. of Energy Facilities", April 1994.

9. TRANSPORTATION

9.1. Basis for Table 9.1

It is assumed that, on average, 325 workers drive 365 times per year to work. Building materials come from the nearest town, and construction waste shipments go to the same town. Assuming 365 trips per year per employee is certainly too high. However, there are many other people who will drive to the construction site during the year (suppliers, marketers, visitors, DOE personnel, inspectors, contract labor, etc.) who are not directly involved in the construction work. By assuming 365 trips per worker per year, an attempt was made to capture the additional traffic.

For the shipment of building materials and construction waste, the following assumptions have been made:

- The capacity of a cement truck is 5-10 yd^3.
- The capacity of flat bed truck-trailer combination carrying steel is 45,000 lb.
- The same capacities apply for the respective waste transport capacities.

<u>NEW MOX FFF</u>:

The amount of material required to construct a new MOX FFF is estimated at :

- 9,216 m^3 of concrete used during 18 months of construction
- 3,611 tons of steel are used during 18 months of construction
- 5% waste is assumed for concrete and steel work

Table 9-1. Transportation to the Site

<table>
<tr><th></th><th>Average Number per Year</th><th>Peak Number per Year</th></tr>
<tr><td>Trips to Site by Workers</td><td>118,625</td><td>173,375</td></tr>
<tr><td>Building material shipments</td><td>830</td><td>1,700</td></tr>
<tr><td colspan="3">Average Distance Shipped, km (mi) 29 km (18 mi)
Note: Aiken, South Carolina is 18 miles from F Area; Augusta, Georgia is 22 from F Area, assumes shipments from Aiken.</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>Construction-generated waste shipments</td><td>52</td><td>75</td></tr>
<tr><td colspan="3">Average Distance Shipped, km (mi) 29 km (18 mi)
Note: Aiken, South Carolina is 18 miles from F Area; Augusta, Georgia is 22 from F Area, assumes shipments to Aiken.</td></tr>
</table>

Table 9-3. Transportation of MOX Fuel to Generic Reactor Sites

Number of Shipments Note: Assumes three SSTs per convoy; a convoy is considered a shipment.	129 PWR assemblies/yr 475 BWR assemblies/yr 2 PWR assemblies per container, 2 containers per truck, total PWR truck loads = 33 11 shipments for PWR 4 BWR assemblies per container, 2 containers per truck, total BWR truck loads = 60, total BWR shipments = 20
Availability of containers	Under design (note 1)
Average container weight, kg (lb)	6,075 kg (13,500 lb)
Average material weight, kg (lb)	2,700 kg (6,000 lb) (note 2)
Average isotopic content	Mass % Content
U-235 0.2 wt %%	0.19%
U-238 99.8 wt %	94.81%
Pu-238 0.03 wt%	0.0015%
Pu-239 92.2 wt%	4.61%
Pu-240 6.46 wt%	0.323%
Pu-241 0.05 wt%	0.0025%
Pu-242 0.1 wt%	0.005%
Am-241 0.9 wt%	0.045%
Average Exposure Rate at 1 m, mrem/hr	very low - note 3
Maximum Anticipated Dose Rate at 1 m, mrem/hr	very low - note 3

9.2. Basis for Table 9-2

Table 9-2 has been removed from the scope of this data call report at the direction of SAIC.

9.3. Basis For Table 9-3

The information cited here was obtained in part from ORNL (Ref. 9-1). ORNL is evaluating the design of MOX fuel containers. The status was summarized as follows (items 1, 2 and part of 3).

1. The MOX fuel shipping container is currently being designed. At this time, there are two MOX fuel containers in the US for of different fuel designs, but they are not yet certified.

2. The fuel assembly weight per container is approximately 6,000 lb for either PWR or BWR fuel; the container can hold either 4 PWR assemblies or 8 BWR assemblies.

3. The exposure rate has not been calculated because the design has not been completed. Because the number of MOX fuel assemblies per container is much lower than for uranium fuel and the shielding is very extensive, the exposure rate is expected to be very low. (continued)
The neutron dose rates have been calculated for a 154 kg (7%) source. For 3 in. of polyethylene surrounding the fuel, the surface dose rate was calculated to be 2 mrem/h, assuming an AM-241 content of 0.5%. At a distance of 3 ft from the shield surface (3 in. poly), where the total dose rate (neutron, primary, and secondary gammas) has dropped to close to 0.1 mrem/h (Ref. 9-2).

Note: *At this time there is no MOX fuel container available that has been certified for* MOX fuel shipments. According to Oak Ridge National Laboratory (ORNL), two containers are available that can accommodate two assemblies each, but they have not been certified.

EIS shipments were based on the following:

- A BWR assembly contains 2.45 kg of Pu.
- A PWR assembly contains 18 kg of Pu.
- 3,500 kg of Pu will be converted to MOX per year.
- The manufacturing mix consists of 2,333 kg of Pu is used for PWR assemblies and 1,166 kg of Pu used for BWR fuel (2/3 PWR and 1/3 BWR).
- If all of the Pu were used for PWR assemblies, the total annual PWR assembly production would be 194 assemblies.
- If all of the Pu were used for BWR assemblies, the total annual BWR assembly production would be 1,429 assemblies.

9.4. References

9-1. Oak Ridge National Laboratory, personal communication between S. Ludwig (ORNL) and W. Barthold (LANL).

9-2. Westinghouse PDS, MOX FFF Conceptual Design, 1994, pp. 2.4-87, 2.4-96, and 2.4-97.

10. QUALITATIVE DEACTIVATION AND DECONTAMINATION DISCUSSION

10.1. Introduction

When the MOX FFF becomes surplus to the DOE's programmatic needs, the facility will undergo deactivation and decontamination (D&D). The description of D&D activities presented in this section assumes that the MOX FFF will have been operated for a nominal period of 10 yr, and the D&D operations will require 3 yr to complete. The building will not be demolished, nor will the site be returned to "greenfield" conditions. Rather, the building will be decontaminated to levels that would permit unrestricted use of the facility for other DOE missions. The deactivated facility will not be used for commercial MOX fuel fabrication after all surplus pit material has been converted to MOX fuel. The MOX FFF buildings will be designed and built to facilitate D&D operations; the facility will be designed so that gloveboxes are easy to disconnect, and flooring and surfaces will be designed for easy decontamination.

10.2. D&D Approach

The MOX FFF uses gloveboxes for all operations from the time of the receipt of plutonium oxide through welding of the finished fuel rods. The gloveboxes and equipment used in the MOX FFF will be removed from the processing line and placed in a central cleaning and packaging facility for D&D. Underlying flooring and other surfaces will be decontaminated. Wastes generated will be packaged and removed to appropriate disposal sites.

10.3. D&D Process Plan

The first activity will be to review the operating record of the facility to determine the number and extent of spills, releases, and cleanup efforts occurring during the MOX FFF operating period. Next, a radiological survey of the facility, its outlying buildings, and their immediate surroundings will be performed. The criteria for cleanup of the facility and the associated D&D plan will be established by the government entity having jurisdiction over the affected area.

10.4. D&D Operations

A contamination survey will be performed before removal of equipment and gloveboxes from the MOX FFF. All contamination will be either removed or fixed in place to eliminate the generation of airborne particulates. Larger items of equipment will be prepared for removal by erecting temporary tents over them. Removal will be performed by workers protected with respiratory equipment and layered anti-contamination clothing. The equipment will be transferred into and out of transporting vehicles through dock seals at both the sending and receiving locations. The transporting vehicles will be lined to prevent the spread of contamination into the vehicles.

Upon receipt at the central cleaning and packaging facility, the contaminated equipment will be weighed and assayed by NDA to ensure that safe mass limits are not exceeded. The assay will validate the facility characterization results and determine if there has been excessive material holdup.

10.5. D&D-Generated Wastes and Emissions

The types of wastes generated during D&D operations will include TRU contamination from plutonium and other actinides processed during the MOX FFF nominal 10-year operating period. Low level wastes will also be generated, as well as some recyclable scrap that can be buried in an authorized landfill. Depending on the D&D methods chosen, airborne and liquid emissions from D&D operations could produce dusts and liquids containing radioactive and/or chemical particulates that would require treatment before discharge to the environment. Liquid treatment may include evaporation, filtration, and solidification. The processes chosen will depend upon the nature and volume of the liquids involved and the desired waste form for disposal.

The D&D plan will endeavor to effectively minimize the volume and weight of TRU waste for disposal and maximize the amount of material that could be released for unrestricted use or be disposed of in unrestricted landfills. Any material not in the above two categories would be sent to a LLW repository, either on site or to a commercial LLW facility.

APPENDIX A

ASSUMPTIONS SUMMARY

A.1. INTRODUCTION

This appendix documents the various assumptions made in support of the preparation of this data call report. In general, the assumptions listed in this appendix may be viewed as applicable to the overall MOX fuel mission. In some cases, other specific assumptions are provided in the various sections and appendices of this report to further clarity of the data presented herein. Therefore, the data and the findings presented in this data call report should be interpreted, with the implied applicable limitations, in the context of these various assumptions.

A.2. MOX FUEL MISSION PROGRAMMATIC ASSUMPTIONS

On January 14, 1997, the Department of Energy issued a "*Record of Decision for the Storage and Disposition of Weapons-Usable Fissile Materials Final Programmatic Environmental Impact Statement*" (ROD). The ROD called for the preparation of site-specific disposition environmental impact statements (EIS) at four candidate DOE sites. The site-specific Environmental Impact Statements are being prepared to provide input for fissile materials disposition programmatic policy formulation. This data call report is provided to support the preparation of a site-specific EIS for the INEEL. To this end, the following programmatic assumptions have been made in conjunction with the preparation of this Data Call Report:

1. The MOX fuel fabrication facility (FFF) programmatic requirements, as outlined in the ROD are addressed in this data call report except for the following:

    a. The production of MOX fuel for Canadian deuterium uranium (CANDU) reactors is not addressed. Data in support of such activities, if authorized, would be provided at that time.

    b. The production of MOX fuel for the Fast Flux Test Facility (FFTF) reactor is not addressed. Data in support of such activities, if authorized, would be provided at that time.

2. The MOX FFF would be implemented, as outlined in the ROD, as a government owned and controlled facility. "Controlled," in this instance, means that the DOE would provide the funding for the MOX FFF and exercise fiduciary responsibility in the allocation of the funding. The DOE would review and oversee the facility design, licensing, construction, and testing. The DOE would provide facility security. The DOE would control the facility throughput by controlling the amount of PuO_2 released for fuel fabrication. The method of facility procurement is provided in a separate MOX FFF

Program Acquisition Strategy (PAS, Ref. A-1) document, which outlines the methodologies by which the facility will be designed, licensed, constructed, tested, and operated.

A.3. OVERALL MOX FACILITY DATA CALL REPORT ASSUMPTIONS

The following overall assumptions apply to the MOX FFF used for the basis of the preparation of this data call report:

1. The data provided to support the preparation of the EIS will have built-in margins to allow flexibility in actual facility design and layout. The margins are not likely to materially alter the findings presented in this data call report.

2. The final design and layout of the MOX FFF depends on the process technology selected for the MOX mission as detailed in the PAS. This selection is currently scheduled for August 1998, at the earliest. Therefore, a preconceptual MOX FFF layout is provided to support the preparation of this data call report. While every reasonable effort has been made to provide best estimate data, there are instances where no MOX FFF data bases have yet been developed that would support this data call. In those instances peer reviewed engineering judgment (see definitions section of this data call report) is used to provide the data requested in the data call.

3. A new MOX FFF will be constructed at the SRS or at one of the other DOE candidate sites.

A.4. MOX FFF SITING

The following assumptions apply to the siting of the MOX FFF:

1. The following four sites are under consideration for building a MOX FFF:

    Pantex Plant (Texas)

    Savanna River Site (South Carolina)

    Idaho National Environmental and Engineering Laboratory (Idaho)

    Hanford Site (Washington)

2. The MOX FFF will be sited inside a security zone as detailed in Section 2 of this report.

A.5. PRODUCTION CAPACITY/CAPABILITY

The following assumptions apply to the MOX FFF capacity and capabilities:

1. The MOX FFF will be designed to fabricate plutonium-uranium mixed-oxide fuel for LWRs at a rate of 3.5-MT Pu metal/yr to process a minimum of 35 MT Pu metal. The facility will begin production on or about 2006 and the mission will be finished on or about 2018 (nominal 12-yr facility life). It is expected that the production period will last approximately 10 yr or more.

2. The MOX FFF will be licensed and regulated by the NRC, as outlined in the PAS.

3. BWR and/or PWR MOX fuel pellets, rods and assemblies will be manufactured at the facility.

4. The MOX FFF will provide facility space for additional MOX fuel manufacturing capability.

5. The MOX FFF shall comply with applicable federal, state, and local environmental, health and safety requirements, and applicable or contract designated DOE Orders. Operations will adhere to federal standards on occupational radiation exposures and as low as reasonably achievable (ALARA) radiation exposure practices.

6. The MOX FFF will incorporate a security infrastructure to protect special nuclear materials (such as those required for a Category I SNM Facility).

7. The plutonium oxide delivered to the MOX FFF meets MOX feed specifications (to be defined in conjunction with the PAS) and is in an unclassified form.

8. Uranium oxide (depleted or natural) delivered to the MOX FFF meets the UO_2 feed specifications (to be defined in conjunction with the PAS).

9. Preassembled enriched UO_2 fuel pins will be delivered to the MOX FFF from commercial vendors for incorporation into MOX fuel bundles when required for certain MOX fuel bundle designs (note: MOX fuel bundles for use in LWR may use MOX fuel pins only, or a combination of MOX fuel pins and UO_2 fuel pins, depending on the nuclear characteristics of the fuel and reactor type).

10. All environmental releases are reported on an annual basis based on maximum throughput of 3.5 MT Pu metal/yr, unless otherwise noted.

11. A 2-yr supply of PuO_2 can be stored at the MOX FFF (secure vaulted space).

12. A 2-yr supply of MOX fuel can be stored at the MOX FFF.

13. Up to a 12-month storage capacity of depleted or natural UO_2 is provided at the MOX FFF. This secure vaulted space is provided for quality assurance and safeguards reasons and is connected to the PuO_2 vault in the preconceptual layout. The larger vaulted space also provides additional flexibility (i.e., surge

capacity) in coordinating production between the Pit Disassembly and Conversion Facility (PDCF) and the possible addition of a third production line. It is expected that normally only about 2 months' supply of UO_2 or DUO_2 will be kept on hand during normal operations.

14. Vaulted space is provided for storage of enriched UO_2 fuel pins.

15. Extensive use is made of HEPA filter banks and other emission-control equipment to minimize air emissions of radioactive material. The facility ventilation systems maintain potentially hazardous areas at lower pressures to minimize any possible material leakage.

16. The preconceptual layout of the MOX FFF uses redundant safety equipment and designs throughout (e.g., dual HVAC systems, standby power) consistent with NRC requirements.

17. The MOX FFF will be constructed as a Category I building.

A.6. MOX FFF OPERATION

The actual design, construction, and operation of a MOX FFF will depend on the MOX FFF supplier selected by the MOX FFF procurement process. It is the intent of this data call report to "bound" the probable operations of such a facility so that an environmental impact assessment can be performed. Generic assumptions applicable to the MOX FFF operations include:

1. A generic operating scenario is assumed that does not require details on equipment specifications and processing line layout.

2. No aqueous processes will be employed at the MOX FFF.

3. The MOX FFF will not have the capability for PuO_2 or UO_2 purification.

4. The MOX FFF size and staffing values used in this data call report are based, in part, on (1) planning and safety documents prepared for potential US privately operated MOX facilities that were to use recycled reactor-grade Pu and on (2) recent studies by commercial vendors as part of the DOE's Plutonium Disposition 1994 Study (e.g. Westinghouse and General Electric - see references in data call report).

5. Feed specification grade PuO_2 will be delivered to the MOX FFF by SST vehicles unless the facility is co-located with the Pit Disassembly and Conversion Facility (PDCF). If co-located with PDCF, then PuO_2 transfers to the MOX FFF may be made by a safe, secure, underground tunnel connecting the PDCF to the MOX FFF.

A.7. MOX FFF SAFETY

Detailed safety assessments will be prepared in conjunction with the actual MOX FFF design, licensing, construction, startup, and operations phases of the fissile material disposition program. However, as part of the data call report, items required for safe operations and which impact the preparation of the EIS used the following assumptions:

1. An adequate safety buffer zone exists between the MOX FFF and the DOE site boundary (1 mile or greater).

2. The MOX FFF accident assessment is based on a generic MOX fabrication process line(s).

3. Best estimate safety data are used rather than bounding estimates whenever possible.

4. Accident initiators, their probabilities for occurrence and materials at risk are identified on a best estimate basis.

A.8. WASTE MANAGEMENT

The waste management assumptions used in this data call report include the following:

1. TRU and mixed TRU-type waste will be treated and packaged for shipment at the MOX FFF. The packaged waste will be shipped to the Pu Disposition Immobilization Facility or to the Waste Isolation Pilot Plant.

2. Hazardous waste is shipped offsite to an authorized Resource Conservation Recovery Act (RCRA) facility for treatment and/or disposal.

3. LLW is appropriately disposed of off site if possible, or otherwise disposed of as contracted by DOE and/or the facility operator.

4. PuO_2 scrap generated during the fuel fabrication process will be reused where possible.

A.9. IAEA INSPECTIONS

The facility would be inspectable by the International Atomic Energy Commission (IAEA). Therefore, IAEA monitoring of special nuclear material (SNM) at the MOX FFF would be facilitated.

A.10. MOX FUEL ASSEMBLY SHIPMENTS

The shipment of MOX fuel from the MOX FFF will be under DOE jurisdiction. Escorted safe secure transport (SST) vehicles will be used to transport the MOX fuel from the FFF to the various commercial reactors which will irradiate the fuel. The following assumptions apply:

1. MOX fuel assemblies will be shipped via SST vehicles.
2. The commercial reactor site(s) will provide accountability, safeguards and security for the MOX fuel once it is delivered to the reactor site.
3. Following irradiation in a commercial reactor(s), the fuel will be transported to a geologic repository pursuant to the Nuclear Waste Policy Act for final disposition.

A.11. LWR FUEL ASSEMBLY DESIGN DETAIL

The PWR fuel assembly is assumed to consist of a 17x17 rod array with 264 fuel rods with a 0.36-in. o.d., a 0.3088 in. pellet o.d. and an active fuel height of 144 in. The remaining 25 positions inside the assembly are occupied by guide thimbles/instrumentation thimbles.

For BWRs, the MOX fuel design is based on the UO_2-like GE-11 design, which employs a 9x9 fuel geometry with partial-length rods. A UO_2-like design has been developed for early use where approximately 36% of the core fuel consists of MOX fuel. For later use, a high-MOX design has been developed that contains only MOX fuel rods and no low-enriched uranium rods. The two BWR fuel assembly designs are characterized as shown in Tables A-1 and A-2.

Table A-1. UO_2-like BWR MOX Design

Location	MOX Rods	Gd Rods	UO_2	Water Rods	Vanished Rod
Upper	18	16	32	2	8
Middle	26	16	32	2	
Lower	26	16	32	2	

Table A-2. High-MOX BWR Design

Location	MOX Rods	Gd Rods	UO_2	Water Rods	Vanished Rod
Upper	46	20	0	2	8
Middle	54	20	0	2	
Lower	54	20	0	2	

A.12. MOX FFF CONSTRUCTION

The construction of the MOX FFF incorporates the following assumptions:

1. Building supplies will be delivered from the nearest city or other regional building material supplier.

2. Facility construction will require 3 yr. Startup testing will require 2 yr (cold 1 yr, hot 1 yr).

3. For BWR and PWR fuel manufacture, a 2:1 ratio between PWRs and BWRs will be assumed; otherwise, the facility will manufacture only one style of LWR fuel and potentially one or more other types (e.g., CANDU fuel).

4. No significant site revisions will be required to accommodate the MOX FFF. This means that the MOX FFF will be located adjacent to an accessible area and that utility services (potable water, electricity, sanitary sewer, communications, etc.) and access roads will require only minor extensions.

5. The following assumptions are made in regard to utilities consumed during construction:

   Electricity: 38,550 Mwh

   Water usage: based on using 9,216 m^3 of concrete for a new facility; water consumption for personal use of 25 gal. per day has been assumed

   Fuel usage: for a new facility: (a) a rolling 4 day, 10 hour construction schedule, (b) four pieces of heavy construction equipment, each fitted with a 550-hp diesel that consumes an average of 10 gal./h for 18 months, (c) one crane consuming 5 gal./h over the following months; an additional 33% margin was added

6. Based on reported data, the following assumptions were made in regard to utilities consumed during operation:

   Electricity: one-half of the consumption of the 200-MT MOX FFF described in the NRC Environmental Report (ER) for the Westinghouse Recycle Fuels Plant of 1973.

Water: one-half of the consumption of the adjusted consumption of a 200 MT MOX FFF described in the NRC ER

Fuel usage: dependent on the site selected.

A.13. MOX FFF OPERATION

Assumptions applicable to the MOX FFF operations include the following:

1. No depletable neutron absorbers are mixed into the MOX fuel powder to form an integral burnable absorber. No coating of pellets with depletable absorbers is done. However, such additions are shown in process flow diagrams should this assumption be overridden in the future.
2. Fuel assembly skeletons are delivered with the appropriate number of UO_2 rods that are either already inserted or delivered separately.
3. All fabrication processes are shielded glovebox operations, except fuel bundle assembly.
4. All materials required for the fabrication process besides the plutonium fuel are assumed to be provided from commercial suppliers in the required amounts and to be suitable for immediate use in the identified processes.
5. MOX fuel bundles not accepted by the utility will be returned to the MOX FFF for disposition.
6. Clean MOX scrap for recycle is 10% of plant throughput.
7. Dirty MOX scrap for disposal is less than 0.5% of plant throughput (based on procurement requirements). Dirty scrap will be sent to the PCIF.
8. Process equipment lifetimes will be greater than the facility usage requirements, thus reducing the amount of contaminated waste coming from equipment replacements.
9. The facility design is such that operators are not required to wear respiratory protection except for off-normal activities.

A.14. WASTE MANAGEMENT DURING OPERATIONS

Waste assumptions applicable to MOX FFF operations include the following:

1. Waste during construction: 5% of the concrete used; 5% of the steel used
2. Air emissions during construction: based on EPA AP-42

3. Waste generated during operation:

3.1. TRU and mixed TRU waste based on Westinghouse Plutonium Disposition Study of 1994

3.2. Mixed LLW: based on NRC ER mixed

LLW: based on NRC ER

Hazardous: based on LA-UR-95-4442

Nonhazardous (sanitary): based on NRC ER

Nonhazardous (other): based on LA-UR-95-4442

3.3 Air emissions (nonradioactive): primarily due to natural gas combustion for heating

3.4 Airborne radioactive releases: based on Westinghouse measured data cited in NRC Environmental Report (ER)

4. DOE will be responsible for disposal of irradiated fuel, TRU wastes and LLW (unmixed and mixed) and is beyond the scope of this data call report.

A.15. TRANSPORTATION DURING CONSTRUCTION

Transportation assumptions during construction include the following:

1. Building materials will be shipped from the nearest city or other regional building material supplier.

2. Construction-generated waste will be shipped to the nearest city or other regional waste-receiving facility.

3. For a new MOX FFF, the average number of workers during construction is 325 for 256 work-days per year; the maximum number is 475 per year.

A.16. TRANSPORTATION DURING OPERATIONS

1. A PWR shipping container can hold four PWR assemblies.

2. A BWR shipping container can hold eight BWR assemblies.

3. During each shipment, three containers are transported to a generic reactor site.

5. The average container weight is 13,500 lb.

6. The average material weight is 6,000 lb.

6. The isotopic compositions are as follows:

uranium: 0.2% U-235

99.8 % U-238

plutonium: less than 1 ppb Pu-236

0.03% Pu-238

92.2% Pu-239

6.46% Pu-240

0.05% Pu-241

0.1% Pu-242

0.9% Am-241 (coming from the decay of Pu-241)

A.17. REFERENCES

A-1. U. S. Dept. of Energy, Office of Fissile Materials Disposition, "Program Acquisition Strategy for Obtaining Mixed Oxide (MOX) Fuel Fabrication and Reactor Irradiation Services (PAS)," July 17, 1997.

APPENDIX B

MOX FFF ACCIDENT ANALYSIS

Facility and Operational Parameters Required for Evaluating the Magnitude of Releases from the MOX FFF

B.1. INTRODUCTION

Fuel fabrication license applications, federal regulations, European experience and the open literature were reviewed to characterize the MOX FFF. With the assistance of personnel experienced in fuels research, design, and operations, the process information is projected to identify the representative quantities and characteristics of fuel materials expected for a MOX FFF. Uranium is only considered when in combination with plutonium, because the radiological hazards of depleted or natural uranium are overshadowed by those of plutonium. References B-1 through B-13 are cited in Tables B-1 through B-23.

B.2. PLANT PRODUCT AND DESIGN CAPACITY

The proposed facility manufactures PuO_2-UO_2 fuel for light water reactors (LWRs). The plant design capacity is 100 MT of fuel per year.

B.3. CONTENT OF PLUTONIUM IN THE FUEL

The LWR fuel is assumed to contain 3 to 5 wt% PuO_2 in natural or depleted UO_2. The LWR fuel fabrication process lines will be used to fabricate fuels for both PWRs and BWRs.

B.4. PLUTONIUM ISOTOPIC COMPOSITION

The plutonium to be used in the fuel fabrication will come from processing of surplus weapons material. For the dose calculation, a specific isotopic distribution of plutonium was chosen as the reference mixture. The isotopic composition of the reference mixture of plutonium is shown in Table B-1, "Isotopic Composition of PuO_2."

B.5. PLUTONIUM INVENTORY

For a facility producing 100 MT of MOX fuel per year, the total facility plutonium inventory will be on the order of 4,000 kg of PuO_2.

B.6. DESIGN LIMITATION IMPOSED BY CRITICALITY CONSIDERATION

One consideration that will limit the amount of plutonium in the process areas is criticality. Criticality safety considerations will either limit the plutonium to a safe mass under specified conditions or the mass will be effectively unlimited (e.g., if the plutonium solution is contained in a cylinder whose diameter is less than the minimum critical diameter, then the cylinder length is not limited and the cylinder can contain an infinite amount of material). Because of its hygroscopic nature and the addition of binders in the processing, the reduction of the safe masses of PuO_2 may be expressed for water uniformly distributed in powder and the pellets. Criticality is also controlled by limiting the moderators, such as maintaining the dryness of the powder. The safe masses during plutonium fuel fabrication are shown in Table B-2, "Criticality Limits (Safe Masses) in Plutonium Fuel Fabrication Facility."

B.7. FUEL PREPARATION

The plutonium is assumed to be received in the form of dry plutonium oxide.

B.8. SCRAP RECOVERY

Clean oxide scrap will be recycled. It is assumed that dirty scrap will not be processed but will be held for disposition later. The waste will be treated.

B.9. FABRICATION PROCESS

To obtain detailed information to support selection of accidents and calculation of consequences of postulated accidents, a specific process (called the reference process) is chosen. The reference MOX facility process is based on the Westinghouse proposed MOX FFF using recycle Pu from spent fuel irradiated in commercial nuclear reactors. The fabrication facility process is shown in Fig. B-1, "Overall MOX Fuel Fabrication Process." The production capacity of the referenced facility is 200 MT of MOX/yr for both PWR and BWR nuclear reactors. A license application, which consists of Environmental Report (ER) and Safety Analysis Report (SAR), was submitted to the Nuclear Regulatory Commission (NRC) in 1973. The fabrication process is similar to the process currently being used by the Europeans.

During the operating life of the MOX facility, a spectrum of incidents may occur, as a result of equipment failure, operator errors, natural phenomena, and other initiators.

B.10. ACCIDENT ANALYSIS METHODOLOGY

Efforts were concentrated on identifying the accidents and their parameters in the process areas having the greatest consequences to the public, workers, and the environment. Criteria for selection of these accidents were the amount of material present, the fraction of plutonium particles in the respirable range, the difficulty in generating plutonium aerosols, and the probability of occurrence and exposure by other means (e.g., criticality). Based on this set of criteria, it is obvious that attention must be focused on four process areas or steps in the fabrication process. These areas are storage, powder treatment, fabrication process, and scrap recovery. In other areas, the material is diluted by UO_2 and/or contained, present in small quantities, or the majority of the particles are not in the respirable range.

Other accidents can be hypothesized for an FFF. However, because of the lack of specific design details in the generic process, the accidents focused on the process areas and operations that offer the greatest consequences to the public, the workers, and the environment. Less dramatic events, such as small powder spills or ruptured transfer lines or gloveboxes, could occur more frequently than the accident cases recommended for further analysis, but consequences to the public, the workers, and the environment would be bounded by analyzed events, and their considerations would be far less instructive. Therefore, only bounding accidents are described in this data report.

To evaluate the consequences of potential radiological accidents, the first steps are to conduct a preliminary radiological hazard analysis, to define the unique process steps/areas, identify the associated radiological hazards, evaluate the radiological hazard, and identify potential accidents with the greatest consequences to the public, the workers, and the environment. The Preliminary Radiological Hazard Analysis (PRHA) process has been used in the chemical industry for many years. The PRHA identifies major radiological hazards and accident scenarios that could result in undesired consequences. For each area of the process, radiological hazards are identified, and possible causes and effects of potential accidents are evaluated. The accident scenarios selected covered the entire spectrum of possible events for a given radiological hazard (i.e., from small consequence events to reasonable worst case conditions, in terms of both accident frequency and consequences). Accident scenarios are prioritized for further analysis. The PRHA performed for the MOX FFF is generic because of the lack of detailed design and operational information.

The frequency levels reported in the PRHA evaluation are for initiator frequency and provide an upper bound on the estimated frequency of the type of scenario considered. The radiological and chemical consequences levels are for unmitigated releases, and it is assumed that the failure or unavailability of engineered and administrative features designed to limit the magnitude of release provide an upper bound on the estimated consequences of the type of scenario considered.

It is necessary to note that while PRHA results bound both frequency and consequences for the identified accidents, there is no expectation that the reported consequences will occur at reported frequencies. In fact, it is generally expected that unmitigated consequences occur at frequencies much lower than those of the accident initiator because of the number or effectiveness of controls protecting against release.

The PRHA was performed using the reference generic process in Fig. B-1, Overall MOX Fuel Fabrication Process, and in Ref. 12 of DOE Standard 3009-94, "Preparation Guide for Nonreactor Nuclear Facility Safety Analysis Report." It identified the radiological hazards and associated accidents and evaluated qualitatively the consequences of the accidents and ranked them based on the consequences to the health and safety of the public, the workers, and the environment. The PRHA evaluation is documented in Table B-3, "MOX Facility Preliminary Hazard Analysis." The accident frequency evaluation levels and radiological and chemical consequence evaluation levels shown in Tables B-4 and B-5, respectively, were used in the evaluation of radiological hazards and consequences of postulated events. Table B-6, "List of Process System/Areas and Potential Accidents Identification," is also used as an input to the hazards analysis. Table B-7 is a summary list of accidents identified as a result of the radiological hazards analysis.

The next step is to characterize the accidents that have been grouped in general groups as design-basis accidents (DBAs) and beyond-design-basis accidents (BDBAs) in order to develop an envelope of conditions that could occur during real facility operations. Accidents are unique occurrences, and their consequences for the most part depend upon the sequence of events leading to and following the initial malfunction and to the amount and characteristics of material initially present in the process.

The DBAs and BDBAs with the greatest consequences to the public, the workers, and the environment are identified for consideration in further analysis in support of the EIS.

A wide range of credible accidents for the MOX facility has been identified, and a spectrum of bounding accidents and their potential consequences are estimated. The bounding accidents that require further analysis to support the EIS were selected and documented in Table B-8, "Summary of Accidents to be Considered for Analysis." These accidents were selected based on their contribution to the overall consequences and are considered to bound the other operational events.

The occurrence frequency per year for each type of accident is established and documented in Table B-9, "Estimates of Accident." These frequencies are reported for FFFs in the 1970s and provide the basis for frequency estimates made for the postulated events. For criticality accidents, the isotopes and their activities are documented in Table B-10, "Radionuclide Yields from Criticality."

The next step is to define the general processes for facility operation (along with expected quantities of material at risk) and physical and chemical forms of the material for each step of the fabrication process. In addition, to estimate the source term for normal operation, parameters related to the mobility, dispersion, and deposition of plutonium compounds must also be identified. Other process parameters include feed isotopic composition, particle size, physical and chemical form of uncontained material, air flow within the enclosure or glovebox, and the temperature of the environment. Other considerations relating primarily to operational practices include batch size, the form of containment within the enclosure/area, the uncontained time within the enclosure/area, and the degree of physical activity during the process step.

In estimating the source term from design-basis conditions, the individual source terms from various process steps have been defined. Because of the inherently conservative approach taken in characterizing the process parameters, the source term for each process step may be an overestimate. Additional conservatism would be interjected because individual source terms would assume that all of the processes occur simultaneously. Because of these considerations, the calculated source term for normal operations should be viewed as a maximum value rather than an expected average.

A mass balance for quantities and flow of radioactive materials at risk for an 8-h shift is calculated. Information in Fig. B-2, "Detailed MOX Fuel Fabrication Process," and Table B-11, "Classification of Process Steps by Directness of Exposure," is used as an input to calculate the material balance for the reference facility. The assumptions for material balance are documented in Table B-12, "Material Balance." The calculated material balance for the 8-h shift is documented in Fig. B-3, "Material quantities and flow in an 8-h shift for a 100-MT MOX/year facility." The material inventories, their physical form, properties, containment and locations for the referenced facility are summarized in Table B-13, "Summary of MOX Process Inventories."

The chemicals at risk, along with their types, locations, quantities, and forms were also identified and documented in Table B-14, "Hazardous Material Inventories." The combustible materials that are generally found in the fuel fabrication facility were identified and documented in Table B-15, "Combustible Materials Inventories in MOX Fuel Plant."

Representative dimensions for the major process areas were identified and documented in Table B-16, "Process Area Dimensions – Generic MOX Facility." The PuO_2 particle sizes were identified and documented in Table B-17, "PuO_2 Particle Characteristics."

B.11. CONSEQUENCES ESTIMATES

The basic process for estimating the consequences of potential accidents is to perform an accident analysis. The accident analysis may involve some or all of the following steps:

A. Identify accident-initiating events associated with the facility.

- Internal initiators (e.g., criticality, fire, explosion)
- External initiators (e.g., tornado, earthquake, flood, airplane crash)

B. Estimate the quantity and method of release of radioactive material to the environment as a result of each initiating event. Estimate scenario frequency based on initiator frequency and availability of process control.

C. Estimate the radiological consequences of each initiating event.

D. Develop latent cancer fatalities (LCF) estimates for an individual accident for the public, and the workers.

Steps A and B were completed and are documented in section 8 and in the supporting tables in this appendix. The sequences of DBAs and BDBAs are presented in section 8.

The source terms for each DBA and BDBA are presented in Tables B-10 and B-18 through B-22.

The accidents identified are considered bounding for postulated accidents that could occur as a result of initiators such as equipment failure, operator error, natural phenomena, and incidents in nearby facilities during the operation of the FFF.

Steps C and D will be performed by the SAIC team, in which for each accident, the consequences to the on-site workers, the maximum off-site individual (MOI) at the site boundary, and the population within the 50-mile zone of the facility are estimated. The LCF for the workers and the public are also estimated. The necessary information and data to perform the consequence analysis and to complete Tables 8-1, 8-2, 8-3 and 8-4 of the data call are provided in this document.

The accidents covered in this document are generic for a MOX facility and applicable to all potential sites. However, site-specific related accidents such as airplane crashes, winds and tornadoes, floods, and man-made hazards are to be addressed by SAIC as applicable to each site.

For the SRS site, it is suggested that the following potential accidents be addressed:

- airplane crash, especially helicopter crashes, since three helicopters operate daily on the site.
- hurricanes, flooding, wind and tornado, and events in the nearby facilities with potential for chemical and radiological releases.

TABLE B-1. Isotopic Composition Of PuO_2 (Values in Atom Percent)[a]			
Isotope	**Weight%**	**Activity Ci/g**	**Half-life Year**
236Pu	∠1ppb	533.86	2.87
238 Pu	0.03	17.8	87.8
239 Pu	92.2	.0616	2.44E4
240 Pu	6.46	.227	6.54E3
241 Pu	0.05	113	15
242 Pu	0.10	.00391	3.87E5
241 Am	0.90	3.24	458
238 U	99.8	3.33E-7	3E-5
235 U	.2	2.14E-6	4.28E-7

[a]Reference B-1 and B-2.

TABLE B-2. Criticality Limits (Safe Masses) in Fuel Fabrication Facility[a]			
Material	**PuO_2/ Pu Mass**	**LWR Fuel 4 wt% PuO_2-96 wt% UO_2/ PuO_2 Mass**	**Pu Mass**
Dry powder	11.3 kg/kg	>3600 kg	>126 kg
Dry pellet	4.86 kg/kg	> 3600 kg	>126 kg
Powder with 1 wt% water	-	>2300 kg	> 81 kg
Pellet with 1 wt% water	-	> 2300 kg	> 81 kg

[a]Reference B-3

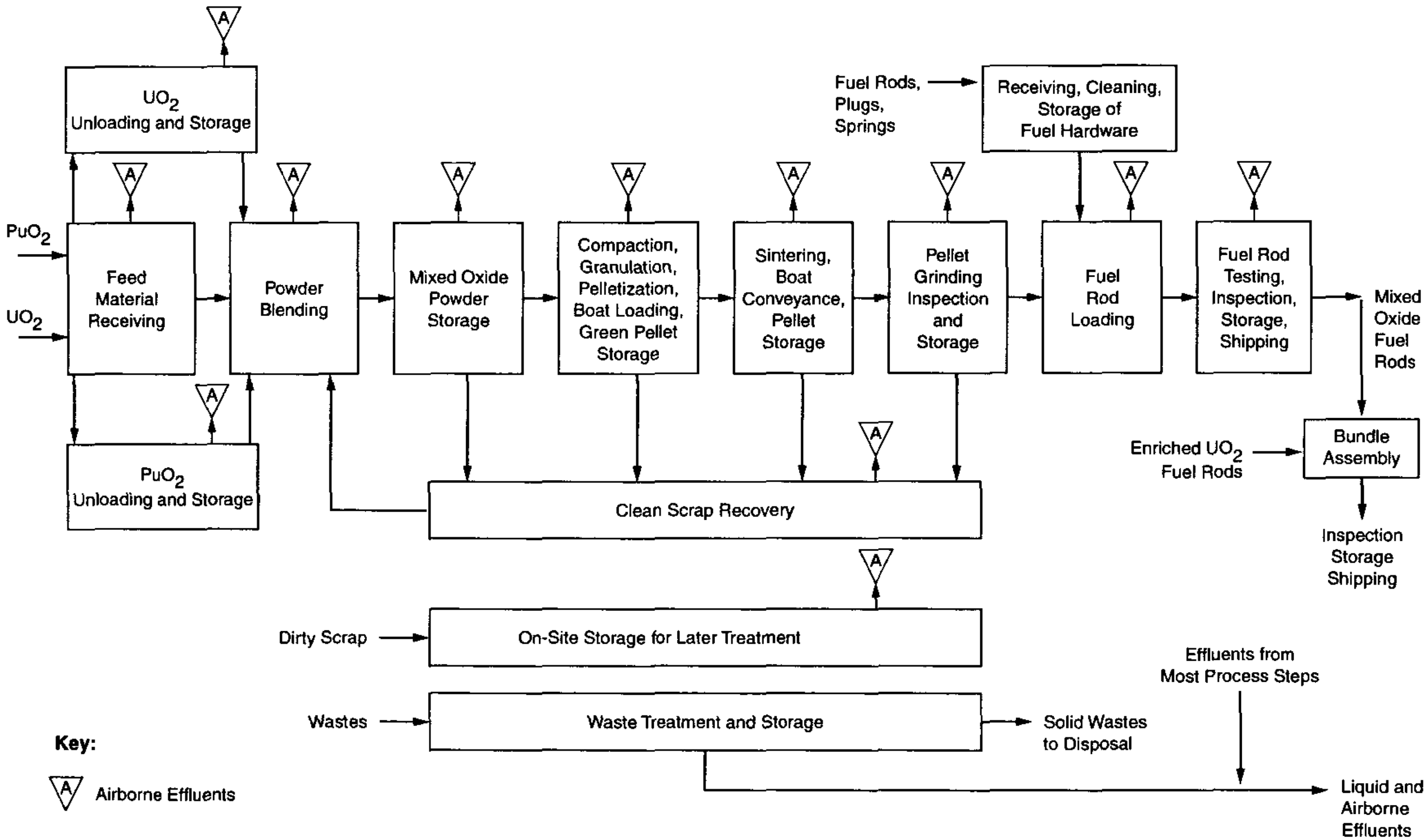


Fig. B-1. Overall MOX fuel fabrication process.

TABLE B-3. MOX Facility Preliminary Radiological Hazard Analysis

Systems/ Subsystems	Potential Accident Description	Causes of Accident	Preventive/Mitigate Features	Characteristic of Source Term	Accident Frequency Level	Unmitigated Consequences Significance, Public/Worker
Receiving dock	Pu container leaking upon receipt	Improper assembly and test	Confinement, barriers	Pu powder, 17 micron average, 4.5 kg containers	Unlikely	Low/medium
	Pu container punctured during receiving	Improper use of fork truck for handling Pu-administrative violation	Confinement, barriers		Unlikely	Low/medium
	Dropped container pinned between truck and dock	Improper handling	Confinement, barriers		Unlikely	Low/medium
	Truck fire	Smoking/ truck crash	Fire protection systems, containers are designed for 1475 F, 30 minutes. fire tests show resistance at higher temperatures		Unlikely	Medium/high

Table B-3. MOX Facility Preliminary Radiological Hazard Analysis (cont)

Systems/ Subsystems	Potential Accident Description	Causes of Accident	Preventive/Mitigate Features	Characteristic of Source Term	Accident Frequency Initiator Level	Unmitigated Consequences Significance, Public/Worker
	Tornado	Natural occurrence during unloading	Pu containers are very resistant . Tornado warning may speed unloading so that the Pu is in the vault at strike time.		Extremely unlikely	High/high
	Flood	Flooding during unloading	Containers, sealing		Extremely unlikely	High/high
	Earthquake	Natural occurrence seismic during unloading. building collapse could damage some containers	Containers are designed to higher "G" seismic loading than earthquake containers; building is designed to higher earthquake level		Extremely unlikely	High/high
Storage Vault	Criticality	Flooding, improper storage	Building is sited and designed to preclude criticality, administrative control	Agglomerated Pu powder, fission gases, neutrons	Extremely unlikely	Medium/high

Table B-3. MOX Facility Preliminary Radiological Hazard Analysis (cont)

Systems/ Subsystems	Potential Accident Description	Causes of Accident	Preventive/Mitigate Features	Characteristic of Source Term	Accident Frequency Initiator Level	Unmitigated Consequences Significance, Public/Worker
	Air plane crash with possibility of fire	Aircraft accident	Building is designed to high structural criteria. fire protection program, spill is possibly limited to only few containers	Pu powder	Extremely unlikely	High/high
	Earthquake	Natural occurrence. building collapse could damage few containers	Building is designed to higher seismic criteria. containers are designed to higher seismic loading.		Extremely unlikely	High/high
Plutonium unloading	Shipping container falls from lift platform	Improper container loading, collapse of wheel or support structure	Container, confinement barriers	Pu powder 4.5 kg Pu/can	Anticipated	Low /medium
	Leak in pneumatic transfer line	wear and abrasion of transfer line	Glovebox, confinement barriers, HEPA filters, radiation alarms		Anticipated	Low/high

Table B-3. MOX Facility Preliminary Radiological Hazard Analysis (cont)

Systems/ Subsystems	Potential Accident Description	Causes of Accident	Preventive/Mitigate Features	Characteristic of Source Term	Accident Frequency Initiator Level	Unmitigated Consequences Significance, Public/Worker
	Blocked transfer line	Improper moisture in powder line is blocked but Pu is not dispersed	Transfer tube, confinement barriers, HEPA filters, radiation alarms		Anticipated	Low/high
	Spill of can after opening	Improper insertion of pneumatic transfer tube overturns can occur	Glovebox, confinement barriers, HEPA filters, radiation alarms		Anticipated	Low/high
	Fire in the drum-out station	Improper introduction of solvent	Administrative control to solvents, confinement barriers, HEPA filters, radiation alarms		Anticipated	Medium/high
	Spill of plutonium outside of glovebox during maintenance	Failure or inability to completely remove Pu from parts for disassembly	Administrative control, confinement barriers	Agglomerated Pu powder, 4.5 kg Pu/can	Anticipated	Low/high

Table B-3. MOX Facility Preliminary Radiological Hazard Analysis (cont)

Systems/ Subsystems	Potential Accident Description	Causes of Accident	Preventive/Mitigate Features	Characteristic of Source Term	Accident Frequency Initiator Level	Consequences Significance, Public/Worker
	Tornado	Natural occurrence	Containers are designed for greater than 100 MPH and certain missiles		Extremely unlikely	High/high
	Earthquake	Natural occurrence	Containers are designed to higher "g" seismic loading than earthquake containers; building is designed to higher earthquake level		Extremely unlikely	High/high
	Flooding	Natural occurrence	Building is sited and designed to preclude criticality, administrative control		Extremely unlikely	High/high
	Airplane crash	Aircraft accident	Building is designed to high structural criteria. fire protection program, spill is possibly limited to only few containers		Extremely unlikely	High/high

Table B-3. MOX Facility Preliminary Radiological Hazard Analysis (cont)

Systems/ Subsystems	Potential Accident Description	Causes of Accident	Preventive/Mitigate Features	Characteristic of Source Term	Accident Frequency Initiator Level	Unmitigated Consequences Significance, Public/Worker
Hopper loading and storage	Failure of transfer line	Powder caused abrasion pipe stress or vibration	Transfer cut off on failure detection, confinement barriers,	Transfer in batches of 4.5 kg transfer out until closure of isolation valve	Anticipated	Low/high
	Fire	Reaction of UO_2 to U_3O_8 exothermic reaction	Administrative control,	Large amount of fissile material	Anticipated	High/high
	Collapse of plutonium hopper supports or hopper container body	Design or fatigue	Quality control over design, inspection, maintenance	Total content of one hopper 225 kg of Pu powder	Anticipated	Low/high
Blending and storage	Pneumatic system failure *criticality*	Wear, abrasion *favorable, geometry,* moderation in bulk blender/ storage	Confinement barriers, HEPA filters *Homogenous* PuO_2/UO_2, partial reflection	Pu powder Pu powder	Anticipated Extremely unlikely	Low/high Medium/high

Table B-3. MOX Facility Preliminary Radiological Hazard Analysis (cont)

Systems/ Subsystems	Potential Accident Description	Causes of Accident	Preventive/Mitigate Features	Characteristic of Source Term	Accident Frequency Initiator Level	Unmitigated Consequences Significance, Public/Worker
Bulk container, powder transport, compaction, granulation pelletizing/ pressing	Criticality	Favorable, geometry, moderation in bulk container storage	Homogenous PuO_2/UO_2, partial reflection	Pu powder	Extremely unlikely	Medium/high
	Hydraulic fluid fire	seal failure improper fluid	Confinement barriers, HEPA filters, fire protection system	Coarse Pu powder	Anticipated	Low/high
Sintering	Hydrogen explosion in the sintering furnace	Improper gas mixture causes explosion; mixing valve failure with oxygen inleakage	Confinement barriers, HEPA filters, radiation alarms	Coarse Pu powder	Anticipated	Medium/high
	Dust spill	Mechanical failure	Confinement barriers, HEPA filters, radiation alarms	Coarse Pu powder	Anticipated	Low/high
	Criticality	Favorable geometry, water cooled furnace moderation	Confinement barriers, HEPA filters, criticality alarms, partial reflection,	Neutrons, iodine, gamma rays and nobles	Extremely unlikely	Medium/high

Table B-3. MOX Facility Preliminary Radiological Hazard Analysis (cont)

Systems/ Subsystems	Potential Accident Description	Causes of Accident	Preventive/Mitigate Features	Characteristic of Source Term	Accident Frequency Initiator Level	Unmitigated Consequences Significance, Public/Worker
	Release during Maintenance	Improper procedures	Administrative control, training, confinement barriers, HEPA filters, radiation alarms	Coarse Pu powder	Anticipated	Low/high
Grinding, loading, inspection, and storage	Abnormal grinding operations criticality	Loss of coolant Favorable geometry	Detection system, confinement barriers, HEPA filters Partial reflection, moderation	Dust like powder Dust Pu/U-like powder	Anticipated Extremely unlikely	Low/medium Medium/high
Rod loading/ rework, inspection, and storage	Dropped pellets Criticality	Operating errors Favorable geometry	Administrative control, training, confinement barriers, HEPA filters Partial reflection, heterogeneous Pu/U	Coarse Pu powder Coarse Pu/U powder	Anticipated Extremely unlikely	Low/medium Medium/high
Improper welding	Dispersed MOX	Operating errors	Administrative control, training, confinement barriers, HEPA filters	Coarse Pu powder	Anticipated	Low/medium

Table B-3. MOX Facility Preliminary Radiological Hazard Analysis (cont)

Systems/ Subsystems	Potential Accident Description	Causes of Accident	Preventive/Mitigate Features	Characteristic of Source Term	Accident Frequency Initiator Level	Unmitigated Consequences Significance, Public/Worker
Fuel assembly fabrication, inspection and storage	Criticality	Favorable geometry, neutron absorber	Full reflection, full interstitial moderation	Coarse Pu/U powder	Extremely unlikely	Medium/high
Fuel shipping	Dropped rod	Operating errors	Administrative control, training, confinement barriers, HEPA filters	Coarse Pu powder	Anticipated	Low/medium
Clean scrap recovery	Criticality	Procedural error	Confinement barriers, HEPA filters, criticality alarms, administrative control, training	Neutrons, iodine, gamma rays and nobles	Extremely unlikely	Medium/high
	Hydrogen explosion in reactor	Oxygen release in reaction; improper ventilation	Confinement barriers, HEPA filters	Coarse Pu powder	Anticipated	Medium/high
	Spill of MOX scrap	Operating errors	Administrative control, training, confinement barriers, HEPA filters	Coarse Pu powder	Anticipated	Low/high

Table B-3. MOX Facility Preliminary Radiological Hazard Analysis (cont)

Systems/ Subsystems	Potential Accident Description	Causes of Accident	Preventive/Mitigate Features	Characteristic of Source Term	Accident Frequency Initiator Level	Unmitigated Consequences Significance, Public/Worker
Dirty scrap handling and storage	Spill	Leak; operating errors	Administrative control, training, confinement barriers, HEPA filters, chemical safety program, administrative control, training	Coarse Pu Powder	Anticipated	Medium/high
	Criticality	Favorable geometry, moderation	Administrative control, training, confinement barriers, HEPA filters, chemical safety program, administrative control, training	Neutrons, Iodine, Gamma Rays, and Noble Gases	Extremely unlikely	Medium/high
Analytical services	Solvent fire in glovebox	Procedural control	Administrative control, training, confinement barriers, HEPA filters, fire protection system	Dry/wet process	Anticipated	Low/high
	Criticality	Favorable geometry, moderation		Dry/wet process	Extremely unlikely	Medium /high

Table B-3. MOX Facility Preliminary Radiological Hazard Analysis (cont)

Systems/ Subsystems	Potential Accident Description	Causes of Accident	Preventive/Mitigate Features	Characteristic of Source Term	Accident Frequency Initiator Level	Unmitigated Consequences Significance, Public/Worker
Final HEPA filter failure	Release of plutonium trapped in the final filter	Equipment failure, over pressure, overloaded filter	Detection system, radiation alarms, inspection, testing and surveillance	Coarse Pu powder	Anticipated	Medium/high
Others	Waste storage fire	Housekeeping, forklift fire	Fire protection program, administrative control, training	Coarse Pu powder	Anticipated	Medium/high

TABLE B-4. Frequency Evaluation Ranges[a]	
Description	**Frequency Range ($yr.^{-1}$)**
Anticipated	$> 10^{-2}$
Unlikely	10^{-4} - 10^{-2}
Extremely Unlikely	10^{-6} - 10^{-4}
Beyond Extremely Unlikely	$< 10^{-6}$

[a]Reference B-12.

TABLE B-5. Radiological and Chemical Consequence Evaluation Level[a,b]		
Consequence Level	**Off Site**	**On Site**
High	> 25 rem, >ERPG-2	> 100 rem, >ERPG-3
Medium	5 < C ≤ 25 rem ERPG-1<C≤ERPG-2	< 25< C ≤100 rem ERPG-2<C≤ERPG-3
Low	.5< C≤ 5 rem PEL-TWA<C≤ EPRG-1	5< C ≤ 25 rem EPRG-1<C≤ EPRG-2

[a]Reference B-12.
[b]The data shown on the tables are standard information used in preliminary hazard analysis for defining event frequency and event consequence evaluation levels.

TABLE B-6. List of Process Systems/Areas and Potential Accidents Identification	
A.	**Receiving Dock** • Pu container leaking upon receipt • Pu container punctured during receiving • Dropped container pinned between truck and dock • Truck fire • Tornado • Flooding • Earthquake
B.	**Storage Vault** • Criticality • Airplane crash and possible fire • Tornado • Earthquake • Flooding • Pu metal fire
C.	**Plutonium Unloading** • Shipping container falls from lift platform • Leak in pneumatic transfer line • Blocked transfer line • Spill of can after opening • Fire in drum out station • Spill of plutonium outside of glovebox during maintenance • Tornado, earthquake, flooding, air crash
D.	**Hopper Loading and Storage** • Failure of transfer line • Collapse of Pu hopper supports or hopper container body • Fire due to self-heating of large amount of fissile material (oxidation of UO_2 to U_3O_8 exothermic reaction) • Fire in the milling operation • Criticality • Spill
E.	**Blending and Storage** • Pneumatic system failure • Criticality • Spill

TABLE B-6. List of Process Systems/Areas and Potential Accidents Identification (cont)	
F.	**Bulk Container, Powder Transport, Compaction, Granulation, Pelletizing (Pressing), and Pellets Storage** • Hydraulic fluid fire • Line failure • Criticality • Spill
G.	**Sintering, Inspection and Pellets Storage** • Hydrogen explosion in the sintering furnace • Dust spill • Criticality • Release during maintenance
H.	**Grinding, Inspection, and Pellets Storage** • Abnormal grinder operations • Criticality • Vacuum systems failure
I.	**Fuel Rod Loading, Rework, Inspection, and Storage** • Dropped pellets • Criticality
J.	**Improper Welding** • Dispersed MOX
K.	**Fuel Assembly Fabrication, Inspection, Storage, and Shipping** • Dropped rod/assembly • Criticality
L.	**Clean Scrap Recovery** • Criticality • Hydrogen explosion in reactor • Spill of MOX scrap
M.	**Dirty Scrap Handling and Storage** • Criticality • Spill
N.	**Analytical Services Facility** • Solvent fire in glovebox • Criticality • Spill
O.	**Final Stage Filter Failure** • Release of Pu trapped in the final HEPA filter due to fire or HEPAs overload

TABLE B-7. Summary List of Postulated Accidents as a Result of the Preliminary Hazards Analysis[a]

Accident	Facility Location	Material Form
Truck Fire	Receiving Dock	Pu Powder
Earthquake	Receiving Dock	Pu Powder
Tornado	Receiving Dock	Pu Powder
Flood	Receiving Dock	Pu Powder
Criticality	Storage Vault	Pu Powder
Tornado	Storage Vault	Pu Powder
Airplane Crash	Storage Vault	Pu Powder
Earthquake	Storage Vault	Pu Powder
Fire (Pu/U Metal)	Storage Vault	Pu Powder
Flood	Storage Vault	Pu Powder
Fire	Plutonium Unloading	Pu Powder
Earthquake	Plutonium Unloading	Pu Powder
Flood	Plutonium Unloading	Pu Powder
Tornado	Plutonium Unloading	Pu Powder
Airplane Crash	Plutonium Unloading	Pu Powder
Fire	Hopper Loading/Storage	Pu/U Powder
Criticality	Powder Blending	Pu/U Powder
Fire	Milling	Pu/U Powder
Criticality	Powder Transport	Pu/U Powder
Criticality	Powder Compaction/Granulation	Pu/U Powder
Criticality	Pellet Pressing, Loading & Storage	Pu/U Powder
Explosion	Sintering/H_2/O_2 mix in furnace	Coarse Pu/U
Criticality	Sintering Furnace, Loading & Storage	Coarse Pu/U
Criticality	Pellet Grinding, Inspection & Storage	Particles Pu/U
Criticality	Clean Scrap Recovery	Coarse Pu/U
Explosion	Clean Scrap Recovery	Coarse Pu/U
Criticality	Dirty Scrap Handling & Storage	Coarse Pu/U
Fire	Final HEPA	Pu/U Powder
Fire	Analytical Services	MOX
Criticality	Analytical Services	Pu/U/MOX
Criticality	Fuel Rods Loading, Inspection & Storage	MOX
Criticality	Fuel Assembly Fabrication & Storage	MOX

[a]This list is based on the potential consequences of the accidents identified in the preliminary radiological hazard analysis. All high-high, high-medium, high-low, medium-high, medium-medium, medium-low, low-high, low-medium combinations of consequences to the public and workers are considered.

TABLE B-8. Summary of Accidents to be Considered for Analysis[a]
Design Basis Accidents • Fire • Criticality • Explosion • Seismic • Tornado • Flood • Airplane crash
Accidents at Nearby Facilities • Fire • Chemical release • Radiological release • Transportation accident • Explosion (natural gas, explosive)
Beyond Design Basis Accidents • Fire • Seismic
[a]The data are based on the hazard analysis and a literature search. These are the types of accidents that were analyzed in Environmental Impact Statement for Nuclear Fuel Cycle Facilities. These accidents are judged to be very infrequent. However, for the purposes of the impact assessment, it is necessary to assume that these accidents can occur in the life of the facility. This is a conservative assumption that may significantly overstate the actual impact expected from these severe, design basis accidents over the life of the facility.

TABLE B-9. Estimates of Accidents Frequency/yr[a,b]

Accident	Frequency/yr	Range
Major facility fire	2E-4	4E-4 - 4E-5
Earthquake intensity IX	2E-5	1E-2 - 10E-8
Flood	1E-4	1E-2 -1E-6
Tornado	6E-4	4E-3 - 6E-6
Explosion in sintering furnace	5E-2	5E-2 - 4E-4
Criticality	8.6E-3	8.6E-3
Airplane crash	1E-5	1E-4 -1E-6

[a]Reference B-3.
[b]These estimates are based on early 1970's data. No specific data from the Europeans are available, and there is no MOX FFF now in the US. The use of these estimates is conservative and considered bounding for the postulated accidents. These estimates were used as the basis for analyzed frequencies and were modified based on the process and controls for the proposed MOX facility.

TABLE B-10. Radionuclide Yields from Criticality[a,b]

Isotope[b]	Fission Product MAR (Ci)[c]	Leak Path Factor (LPF)[d]	Damage Ratio (DR)[d]	Airborne Release Fraction (ARF)[d]	Respirable Fraction (RF)[d]	Source Term (Ci)
I-131	1.1E+01	1.0	1.0	5.0E-02	1.0	0.55
I-132	1.2E+03	1.0	1.0	5.0E-02	1.0	60.00
I-133	1.6E+03	1.0	1.0	5.0E-02	1.0	80.00
I-134	4.3E+03	1.0	1.0	5.0E-02	1.0	215.00
I-135	4.5E+02	1.0	1.0	5.0E-02	1.0	22.50
Xe-131m	1.0E-01	1.0	1.0	5.0E-01	1.0	0.05
Xe-133m	2.2E+0	1.0	1.0	5.0E-01	1.0	1.10
Xe-133	2.7E+01	1.0	1.0	5.0E-01	1.0	135.00
Xe-135m	3.3E+03	1.0	1.0	5.0E-01	1.0	1650.00
Xe-135	4.1E+02	1.0	1.0	5.0E-01	1.0	205.00
Xe-137	4.9E+04	1.0	1.0	5.0E-01	1.0	24500.00
Xe-138	1.1E+04	1.0	1.0	5.0E-01	1.0	5500.00
Kr-83m	1.1E0+1	1.0	1.0	5.0E-01	1.0	5.50
Kr-85m	7.1E+01	1.0	1.0	5.0E-01	1.0	35.50
Kr-85	8.1E-04	1.0	1.0	5.0E-01	1.0	0.000405
Kr-87	4.3E+02	1.0	1.0	5.0E-01	1.0	215.00
Kr-88	2.3E+02	1.0	1.0	5.0E-01	1.0	115.00
Kr-89	1.3E+04	1.0	1.0	5.0E-01	1.0	6500.00
Pu-238	5.9E-04	1.0	1.0	1.0E-05[e]	1.0	5.9E-09
Pu-239	2.7E-05	1.0	1.0	1.0E-05[e]	1.0	2.7E-10
Pu-240	5.8E-05	1.0	1.0	1.0E-05[e]	1.0	5.8E-10
Pu-241	1.8E-02	1.0	1.0	1.0E-05[e]	1.0	1.8E-07
Pu-242	4.3E-07	1.0	1.0	1.0E-05[e]	1.0	4.3E-12
Am-241	2.4E-05	1.0	1.0	1.0E-05[e]	1.0	2.4E-10
TOTAL						3.696E+04

[a]References B-4, B-11, and B-13.

[b]From Regulatory Guide 3.35, Table 1, for solid and liquid criticalities with 10E+19 fissions (Ref. B-11).

[c]From Regulatory Guide 3.35, paragraph C.2.a (Reference 11).

[d]LPF, DR, ARF and RF (Ref. B-13, Section 6.3.2, page 6-23).

[e]Two stages of HEPA filters (Ref. B-4).

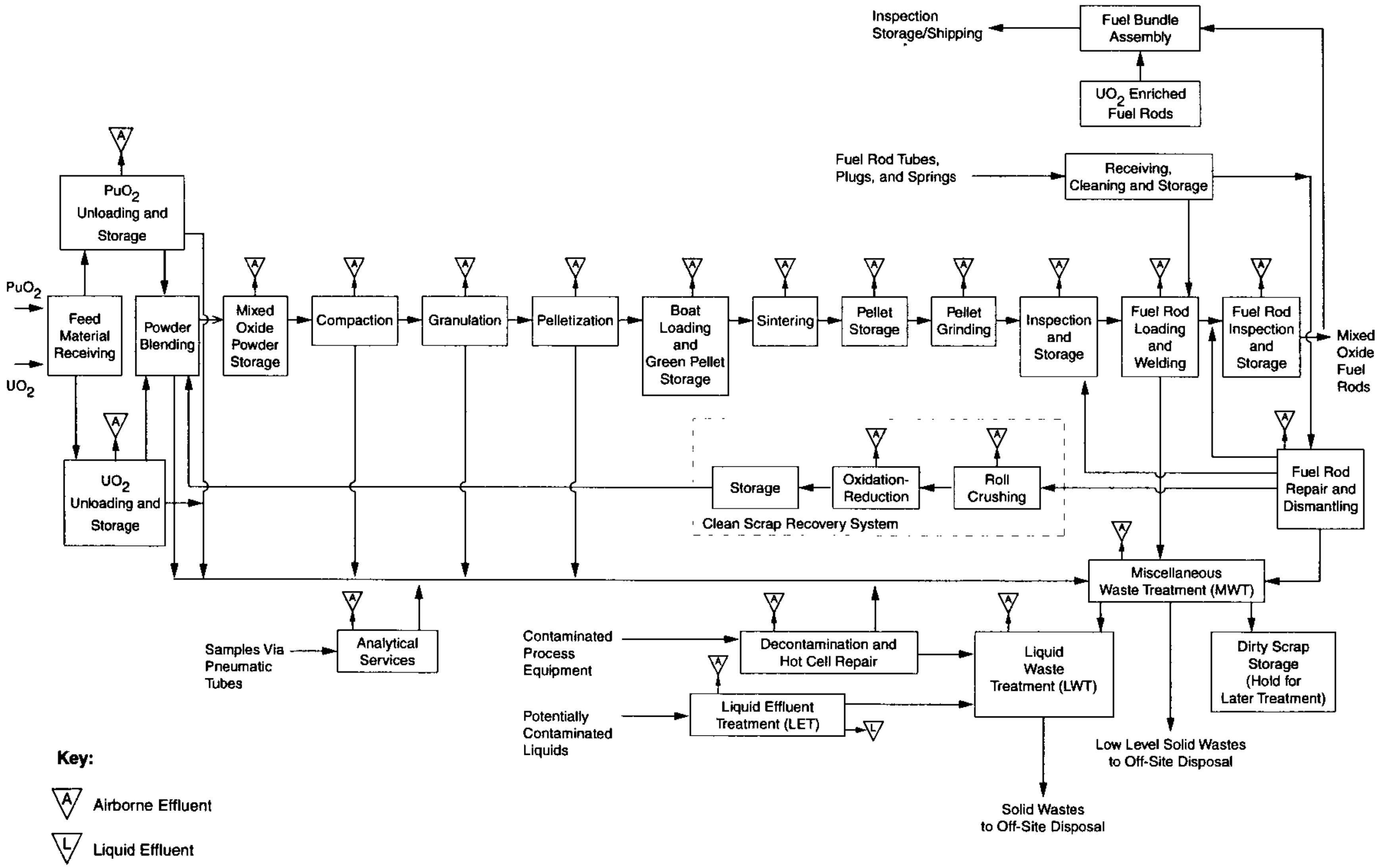


Fig. B-2. Detailed MOX fuel fabrication process.

TABLE B-11. Classification of Process Steps By Directness of Exposure[a]

Process Step	Type of Operation
Receiving, handling, storage of UO_2, and PuO_2 shipping containers	Contact with container
UO_2 unloading	Semicontact[b]
PuO_2 unloading	Remote[c]
Blending and pellet preparation	Remote
Fuel rod loading and welding	Contact
Testing and Inspection	Contact
Shipping	Contact
Scrap handling	Contact
Clean scrap recovery	Remote
Maintenance	Contact after decontamination

[a]Reference B-3.
[b]Drums are handled by standard methods. Operators do not normally contact the powder and extreme caution is used.
[c]Glovebox operation.

TABLE B-12. Material Balance (Quantities and Flow) in an 8-Hour Shift for 100 MT MOX/year[a]
Assumptions
• 4.048 MT of PuO_2/yr. • 100 MT MOX/yr. production capacity • 96.95 MT D/UO_2. • 10% total recycle scrap • 0.5 % dirty scrap • PuO_2 received in 4.5 kg certified containers • PuO_2 shipment contains 38 containers/shipment • UO_2 received in 55-gal. drums, 250 kg/drum, 70 drums/truck shipment • PuO_2 in storage 7.0 MT • D/UO_2 in storage 100 MT • Finished MOX fuel rods in storage 8800 fuel rods • Facility operates 24 h, 3 shifts/day (back shift with reduced operations see section 6) • 1 yr = ~1000 shifts (pelleting and sintering other operation may be only 2 shifts/ day) • 1 week = 20 shifts • 1 shift between run out blends • 1 subblend = 225 kg MOX • MOX fuel composition is 4.5-5 w/% PuO_2+ 95 w/% UO_2 • 1 pellet = 5 g of MOX • Tray limits max. 4.8 kg of MOX • Finished pellet storage max. 3.5 MTHM • 1 fuel rod = 360 pellets = 1.8 kg of MOX =72 g of PuO_2 in 1 fuel rod • 50 fuel rods per channel in storage
[a]References B-3, B-4, B-5, B-8, and B-10.

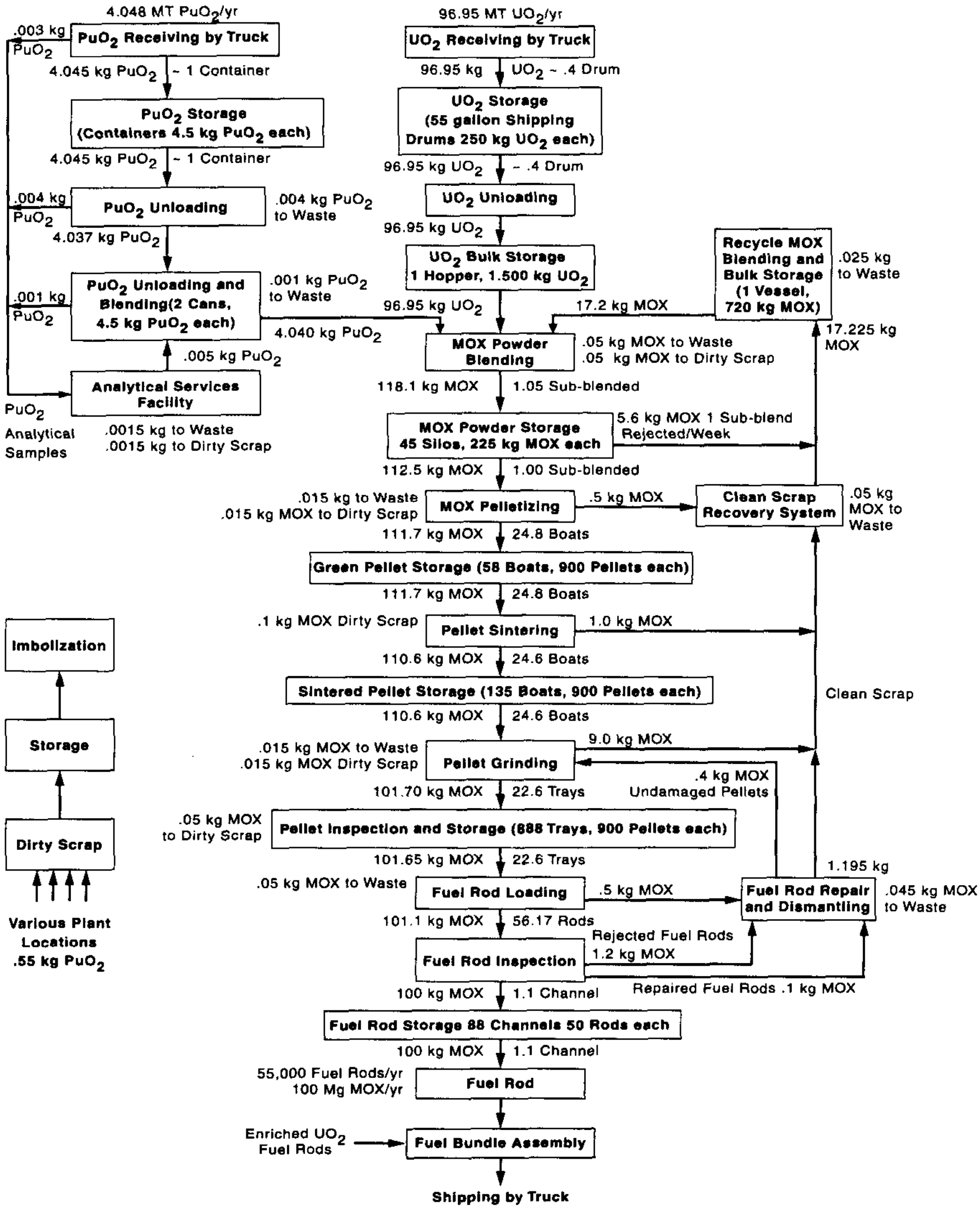


Fig. B-3. Material balance in an 8 h shift for 100-MT MOX/yr.

TABLE B-13. Summary of MOX Process Inventories[a]

Location	Quantity (kg)	Dispensability Properties	Physical Form	Containment	Material
Receiving Area	171 kg 1750 kg	Insoluble, dispersible, respirable	Powder Powder	4.5 kg container 40 kg can	PuO_2 D/UO_2
Storage Area	10,000 kg 100,000 kg	Insoluble, nonrespirable, nondispersible	Powder Powder	Vault, 4.5 kg/can 40 kg can	PuO_2 D/UO_2
Unloading Vessel and Hopper Storage	9.0 kg 21.0 kg	Insoluble, dispersible, respirable	Powder Powder	Vessels Hopper	PuO_2 D/UO_2
Powder Blending Process	118.10 kg 4.040 kg PuO_2, 96.95 kg D/UO_2, 17.2 kg clean recycle mix	Insoluble, dispersible, respirable	Powder	Blender	MOX PuO_2 D/UO_2 MOX
MOX Powder Storage Processing Vault	10,000 kg 500 kg PuO_2, 9500 kg D/UO_2	Insoluble, dispersible, respirable	Powder	Silos	MOX
Compaction Process	118.1 kg	Insoluble, ranging from respirable to nonrespirable, generally dispersible	Powder	Vessel	MOX
Granulating Process	118.1 kg	Insoluble, ranging from respirable to nonrespirable, generally dispersible	Granulate	Vessel	MOX
Pelleting Process	112.5 kg	Insoluble, nonrespirable, nondispersible	Pellets	Press	MOX
Boat Loading	111.7 kg	Insoluble, nonrespirable, nondispersible	Pellets	Boat	MOX
Green Pellet Storage	261 kg	Insoluble, nonrespirable, nondispersible	Pellets	Boat	MOX

[a]The material balance based on the referenced plant 200-MT MOX/yr has been scaled to the 100-MT MOX /yr plant (see Refs. B-2, B-3, and B-10).

Table B-13. Summary of MOX Process Inventories (cont.)					
Location	**Quantity (kg)**	**Dispersibility Properties**	**Physical Form**	**Containment**	**Material**
Sintering and Storage	111.7 kg 607.5 kg	Insoluble, nonrespirable, nondispersible	Pellets	Furnace Boat	MOX
Pellet Grinding and Storage	110.6 kg 3996 kg	Insoluble, nonrespirable, nondispersible	Pellets	Grinder Trays	MOX
Fuel Rod Loading	101.1 kg	Insoluble, nonrespirable, nondispersible	Pellets	Trays	MOX
Fuel Rod Storage	4400 rods 15,840 kg	Insoluble, nonrespirable, nondispersible	Fuel rods	Channel	MOX
Fuel Shipment Loading	288 kg	Insoluble, nonrespirable, dispersible	Fuel assemblies	Containers	MOX
Clean Scrap Recovery Area	17.25 kg	Insoluble, ranging from respirable to nonrespirable, generally dispersible	Powder fine, grinder	Vessel	MOX
Dirty Scrap Area	0.55 kg	Insoluble, ranging from respirable to nonrespirable, generally dispersible	Powder fine, grinder	Containers	MOX
Analytical Services	0.008 kg	Insoluble, dispersible, respirable	Powder fine, solutions	Sample vessel	MOX, Pu, U

TABLE B-14. Hazardous Material Inventories[a]	
Location	**Quantity[b] (lb)**
Service Laboratory	
H_2SO_4	50
HNO_3	25
HCl	15
Lab Scrubber	
$NaNO_3$	3100
NaOH	500
Blending	
Polyethylene glycol	700
Pressing	
Zinc stearate	700
Cooling Tower Blowdown	
Orthophosphate	600

[a]References B-3, B-4, B-5, and B-10.
[b]These are the total quantities used in the process/year.

TABLE B-15. Combustible Materials Inventory in MOX Fuel Plant[a,b]		
Material	**Form**	**Quantity (lb)**
Cellulosics	Paper, rags, wipes	50
Hydraulic Fluid	Lubricants	48
Polymethyl metacrylate	Glovebox viewing windows	226
Polyvinyl chloride (plastic)	Wrapping, bagging, covers	8
Alcohol	Liquid	2

[a]References B-3, B-4, B-5, and B-10.
[b]These are the typical combustibles that are often found in the fuel fabrication facility.

TABLE B-16. Process Area Dimensions–Generic MOX Facility[a]	
Process Area	**Dimensions LxWxH in Feet[b,c]**
Manufacturing Area	224x75x18
Furnace area	60x36x18
Fuel fabrication area	72x36x18
PuO_2 storage	69x24x18
Hot repair area(s)	50x17x18
Powder storage and scrap recovery	120x32x23
Analytical Services Area	120x78x18
Receiving Dock Truck Well	80x44x18
Rod Inspection Area	190x150x10
Shipping dock truck well	100x26x18
Fuel storage area	24x23x10
Rod repair and dismantling	78x26x18
Rod inspection room	170x69x10
Feed Materials and Personnel Control Area	120x72x18
UO_2 storage	45x24x18
Cold chemical storage	48x24x18
Feed materials receiving room	120x72x18
Filter Room Area	93x25x18

[a]References B-3, B-4, B-5, and B-10.
[b]Some dimensions are scaled down and other dimensions remained the same as in the referenced facility.
[c]These dimensions are representative and conservative.

TABLE B-17. PuO_2 Particle Characteristics[a]	
Mean particle size	17.5 micron, average
Surface area	6.844 m^2/g
Oxygen to metal ratio	2.0265
% Plutonium	85.84

[a]Reference B-1.

TABLE B-18. Design-Basis Fire in the MOX Pelleting Press Area

Isotope	Weight %	Inventory (kg)	Specific Activity (Ci/g)	Material at Risk (Ci)	Leak Path Factor (LPF)	Damage Ratio (DR)	Airborne Release Fraction (ARF)	Respirable Fraction (RF)	Source Term (Ci)
236Pu	∠1ppb	0.00	533.86	0.00	1.0E-05	1.0	6.0E-03	0.01	
238 Pu	0.03	1.69E-03	17.8	30.04	1.0E-05	1.0	6.0E-03	0.01	
239 Pu	92.2	5.187	0.0616	319.47	1.0E-05	1.0	6.0E-03	0.01	
240 Pu	6.46	0.363	0.227	82.49	1.0E-05	1.0	6.0E-03	0.01	
241 Pu	0.05	2.815E-03	113	317.81	1.0E-05	1.0	6.0E-03	0.01	
242 Pu	0.10	5.63E-03	0.00391	0.022	1.0E-05	1.0	6.0E-03	0.01	
241 Am	0.90	0.0506	3.24	163.94	1.0E-05	1.0	6.0E-03	0.01	
Pu Total	100%	5.625							
238 U/D	99.8	106.66	3.33E-07	0.03552	1.0E-05	1.0	6.0E-03	0.01	
235 U	.2	0.21375	2.14E-06	4.57E-04	1.0E-05	1.0	6.0E-03	0.01	
U Total	100%	106.875							
		112.5kg MOX		9.138E+02					5.48E-07

TABLE B-19. Design-Basis Explosion in the Sintering Furnace

Isotope	Weight %	Inventory (kg)	Specific Activity (Ci/g)	Material at Risk (Ci)	Leak Path Factor LPF)	Damage Ratio (DR)	Airborne Release Fraction (ARF)	Respirable Fraction (RF)	Source Term (Ci)
236Pu	∠1ppb	0.00	533.86	0.00	1.0E-05	1.0	0.01	1.0	
238 Pu	0.03	1.66E-03	17.8	29.53	1.0E-05	1.0	0.01	1.0	
239 Pu	92.20	5.098	0.0616	314.08	1.0E-05	1.0	0.01	1.0	
240 Pu	6.46	.357	0.227	81.09	1.0E-05	1.0	0.01	1.0	
241 Pu	0.05	2.76E-03	113	312.45	1.0E-05	1.0	0.01	1.0	
242 Pu	0.10	5.53E-3	0.00391	0.0216	1.0E-05	1.0	0.01	1.0	
241 Am	0.90	0.050	3.24	162.00	1.0E-05	1.0	0.01	1.0	
Pu Total	100%	5.53							
238 U/D	99.8	104.86	3.33E-07	3.482E-02	1.0E-05	1.0	0.01	1.0	
235 U	.2	4.634	2.14E-06	9.92E-03	1.0E-05	1.0	0.01	1.0	
U Total	100%	105.07							
		110.6kg MOX		8.99E+2					8.99E-05

TABLE B-20. Design-Basis Earthquake[a]

Location	Inventory kg	Material at Risk (MAR) kg	Dispersibility Properties	Physical Form	Containment	Material	Isotope Weight %	Specific Activity (Ci/g)	Leak Path Factor (LPF)	Damage Ratio DR)	Airborne Release Fraction (ARF)	Respirable Fraction (RF)	Source Term (g)mix
Receiving Area	171 kg 1750 kg	One Container (4.5 kg) One Drum (40 kg)	Insoluble, dispersible, respirable	Powder Powder	4.5 kg container 40 kg can	PuO_2 D/UO_2	236Pu ∠1ppb 238 Pu 0.03 239 Pu 92.2 240 Pu 6.46 241 Pu 0.05 242 Pu 0.10 241 Am 0.90 238 U/D 99.8 235 U 0.2	533.86 17.8 0.0616 0.227 113.00 0.00391 3.240 3.33E-07 2.14E-06	N/A	0.00	N/A	N/A	0.00
Storage Area	10,000 kg 100,000 kg	One Container (4.5 kg) One Drum (40 kg)	Insoluble, nonrespirable, nondispersible	Powder Powder	Vault, 4.5 kg/ can 40 kg drum	PuO_2 D/UO_2	236Pu ∠1ppb 238 Pu 0.03 239 Pu 92.2 240 Pu 6.46 241 Pu 0.05 242 Pu 0.10 241 Am 0.90 238 U/D 99.8 235 U 0.2	533.86 17.8 0.0616 0.227 113.00 0.00391 3.240 3.33E-07 2.14E-06	N/A	0.00	N/A	N/A	0.00
Unloading Vessel and Hopper Storage	9 kg 21 kg	9 kg 21 kg	Insoluble, dispersible, respirable	Powder Powder	Cans Hopper	PuO_2 D/UO_2	236Pu ∠1ppb 238 Pu 0.03 239 Pu 92.2 240 Pu 6.46 241 Pu 0.05 242 Pu 0.10 241 Am 0.90 238 U/D 99.8 235 U 0.2	533.86 17.8 0.0616 0.227 113.00 0.00391 3.240 3.33E-07 2.14E-06	N/A	0.00	N/A	N/A	0.00
Powder Blending Process	118.10 kg 4.040 kg PuO_2, 96.95 kg D/UO_2, 17.2 kg clean recycle mix	118.10 kg	Insoluble, dispersible, respirable	Powder	Blender	MOX PuO_2 D/UO_2 MOX	236Pu ∠1ppb 238 Pu 0.03 239 Pu 92.2 240 Pu 6.46 241 Pu 0.05 242 Pu 0.10 241 Am 0.90 238 U/D 99.8 235 U 0.2	533.86 17.8 0.0616 0.227 113.00 0.00391 3.240 3.33E-07 2.14E-06	1.0E-05	1.0	2.0E-03	.3	3.55E-05[b]
MOX Powder Storage	10,000 kg 500 kg PuO_2, 9500 kg D/UO_2	500 kg	Insoluble, dispersible, respirable	Powder	Silos	MOX	236Pu ∠1ppb 238 Pu 0.03 239 Pu 92.2 240 Pu 6.46 241 Pu 0.05 242 Pu 0.10 241 Am 0.90 238 U/D 99.8 235 U 0.2	533.86 17.8 0.0616 0.227 113.00 0.00391 3.240 3.33E-07 2.14E-06	N/A	N/A	N/A	N/A	0.00
Compaction Process	118.1 kg	118.1 kg	Insoluble, ranging from respirable to nonrespirable, generally dispersible	Powder	Vessel	MOX	236Pu ∠1ppb 238 Pu 0.03 239 Pu 92.2 240 Pu 6.46 241 Pu 0.05 242 Pu 0.10 241 Am 0.90 238 U/D 99.8 235 U 0.2	533.86 17.8 0.0616 0.227 113.00 0.00391 3.240 3.33E-07 2.14E-06	1.0E-05	1.0	2.0E-03	.3	3.55E-05[b]
Granulating Process	118.1 kg	118.1 kg	Insoluble, ranging from respirable to nonrespirable, generally dispersible	Granulate	Vessel	MOX	236Pu ∠1ppb 238 Pu 0.03 239 Pu 92.2 240 Pu 6.46 241 Pu 0.05 242 Pu 0.10 241 Am 0.90 238 U/D 99.8 235 U 0.2	533.86 17.8 0.0616 0.227 113.00 0.00391 3.240 3.33E-07 2.14E-06	1.0E-05	1.0	ARF/RF =	2.1E-05	1.24E-06[c]

TABLE B-20. Design-Basis Earthquake[a] (cont.)

Location	Inventory kg	Material at Risk (MAR) kg	Dispersibility Properties	Physical Form	Containment	Material	Isotope Weight %	Specific Activity (Ci/g)	Leak Path Factor (LPF)	Damage Ratio (DR)	Airborne Release Fraction (ARF)	Respirable Fraction (RF)	Source Term (g)mix
Pelleting Process	112.5 kg	112.5 kg	Insoluble, nonrespirable, nondispersible	Pellets	Press	MOX	236Pu ∠1ppb 238 Pu 0.03 239 Pu 92.2 240 Pu 6.46 241 Pu 0.05 242 Pu 0.10 241 Am 0.90 238 U/D 99.8 235 U 0.2	533.86 17.8 0.0616 0.227 113.00 0.00391 3.240 3.33E-07 2.14E-06	1.0E-05	1.0	ARF/ RF =	2.1E-05	1.18E-06[c]
Boat Loading	111.7 kg	111.7 kg	Insoluble, nonrespirable, nondispersible	Pellets	Boat	MOX	236Pu ∠1ppb 238 Pu 0.03 239 Pu 92.2 240 Pu 6.46 241 Pu 0.05 242 Pu 0.10 241 Am 0.90 238 U/D 99.8 235 U 0.2	533.86 17.8 0.0616 0.227 113.00 0.00391 3.240 3.33E-07 2.14E-06	1.0E-05	1.0	ARF/ RF =	2.1E-05	2.74E-06[c]
Green Pellet Storage	261kg	261 kg	Insoluble, nonrespirable, nondispersible	Pellets	Boat	MOX	236Pu ∠1ppb 238 Pu 0.03 239 Pu 92.2 240 Pu 6.46 241 Pu 0.05 242 Pu 0.10 241 Am 0.90 238 U/D 99.8 235 U 0.2	533.86 17.8 0.0616 0.227 113.00 0.00391 3.240 3.33E-07 2.14E-06	1.0E-05	1.0	ARF/ RF =	2.1E-05	1.18E-06[c]
Sintering and Storage	111.7 kg 607.5 kg	111.7 kg 607.5 kg	Insoluble, nonrespirable, nondispersible	Pellets	Furnace Boat	MOX	236Pu ∠1ppb 238 Pu 0.03 239 Pu 92.2 240 Pu 6.46 241 Pu 0.05 242 Pu 0.10 241 Am 0.90 238 U/D 99.8 235 U 0.2	533.86 17.8 0.0616 0.227 113.00 0.00391 3.240 3.33E-07 2.14E-06	1.0E-05 N/A	1.0 0.00	ARF/ RF = N/A	2.1E-05 N/A	1.1E-06[c] 0.00
Pellet Grinding and Storage	110.6 kg per 8-hours 3996 kg in 888 trays	13.825 kg 4.5 kg per tray	Insoluble, nonrespirable, nondispersible	Pellets	Grinder Trays	MOX	236Pu ∠1ppb 238 Pu 0.03 239 Pu 92.2 240 Pu 6.46 241 Pu 0.05 242 Pu 0.10 241 Am 0.90 238 U/D 99.8 235 U 0.2	533.86 17.8 0.0616 0.227 113.00 0.00391 3.240 3.33E-07 2.14E-06	N/A	0.00	N/A	N/A	0.00
Fuel Rods and Storage	101.1 kg in 22.46 trays	4.5 kg per tray	Insoluble, nonrespirable, nondispersible	Pellets	Trays	MOX	236Pu ∠1ppb 238 Pu 0.03 239 Pu 92.2 240 Pu 6.46 241 Pu 0.05 242 Pu 0.10 241 Am 0.90 238 U/D 99.8 235 U 0.2	533.86 17.8 0.0616 0.227 113.00 0.00391 3.240 3.33E-07 2.14E-06	N/A	0.00	N/A	N/A	0.00

TABLE B-20. Design-Basis Earthquake[a] (cont.)

Location	Inventory kg	Material at Risk (MAR) kg	Dispersibility Properties	Physical Form	Containment	Material	Isotope Weight %	Specific Activity (Ci/g)	Leak Path Factor (LPF)	Damage Ratio (DR)	Airborne Release Fraction (ARF)	Respirable Fraction (RF)	Source Term (g)mix
Fuel Rod Storage	4400 rods 15840 kg	None	Insoluble, nonrespirable, nondispersible	Fuel Rods	Channel	MOX	236Pu ∠1ppb 238 Pu 0.03 239 Pu 92.2 240 Pu 6.46 241 Pu 0.05 242 Pu 0.10 241 Am 0.90 238 U/D 99.8 235 U 0.2	533.86 17.8 0.0616 0.227 113.00 0.00391 3.240 3.33E-07 2.14E-06	N/A	0.00	N/A	N/A	0.00
Fuel Shipment Loading	288 kg	None	Insoluble, nonrespirable, dispersible	Fuel Assemblies	Containers	MOX	236Pu ∠1ppb 238 Pu 0.03 239 Pu 92.2 240 Pu 6.46 241 Pu 0.05 242 Pu 0.10 241 Am 0.90 238 U/D 99.8 235 U 0.2	533.86 17.8 0.0616 0.227 113.00 0.00391 3.240 3.33E-07 2.14E-06	N/A	0.00	N/A	N/A	0.00
Dirty Scrap Area	0.55 kg	0.55 kg	Insoluble, ranging from respirable to nonrespirable, generally dispersible	Powder fine and Grinder	Containers	MOX	236Pu ∠1ppb 238 Pu 0.03 239 Pu 92.2 240 Pu 6.46 241 Pu 0.05 242 Pu 0.10 241 Am 0.90 238 U/D 99.8 235 U 0.2	533.86 17.8 0.0616 0.227 113.00 0.00391 3.240 3.33E-07 2.14E-06	1.0E-05	0.5 0.5	2.0E-03 ARF/RF=	0.3 2.1E-05	8.3E-08[b] 3.0E-09[c]
Analytical Services	0.008 kg	0.008	Insoluble, dispersible, respirable	Powder fine, solutions	Sample Vessel	MOX, Pu, U	236Pu ∠1ppb 238 Pu 0.03 239 Pu 92.2 240 Pu 6.46 241 Pu 0.05 242 Pu 0.10 241 Am 0.90 238 U/D 99.8 235 U 0.2	533.86 17.8 0.0616 0.227 113.00 0.00391 3.240 3.33E-07 2.14E-06	2.0E-06	0.5 0.5	2.0E-03 ARF/RF=	0.3 2.1E-05	2.4E-10[b] 8.4E-12[c]

[a]The material balance is based on the referenced plant 200-MT MOX/yr scaled to a 100-MT MOX /yr plant (see Refs. B-3, B-5, and B-10).
[b]Reference 13, section 4.4.3.1.3, page 4-82.
[c]Reference 13, section 4.3.3, pg. 4-52 (density =10.96g/cm, h=400cm).

TABLE B -21. BEYOND DESIGN BASIS FIRE IN MOX BLENDING AND BULK STORAGE AREA

Isotope	Weight %	Inventory (Kg)	Specific Activity (Ci/g)	Material at Risk (Ci)	Leak Path Factor (LPF)	Damage Ratio (DR)	Airborne Release Fraction (ARF)	Respirable Fraction (RF)	Source Term (Ci)
236Pu	∠1ppb	0.00	533.86	0.00	1.4E-02	1.0	6.0E-03	0.01	
238 Pu	0.03	3.38E-03	17.8	60.08	1.4E-02	1.0	6.0E-03	0.01	
239 Pu	92.2	10.373	0.0616	638.95	1.4E-02	1.0	6.0E-03	0.01	
240 Pu	6.46	.727	0.227	164.97	1.4E-02	1.0	6.0E-03	0.01	
241 Pu	0.05	5.625E-03	113	635.63	1.4E-02	1.0	6.0E-03	0.01	
242 Pu	0.10	0.01125	0.00391	0.04399	1.4E-02	1.0	6.0E-03	0.01	
241 Am	0.90	0.1013	3.24	328.05	1.4E-02	1.0	6.0E-03	0.01	
Pu Total	100%	11.25							
238 U/D	99.8	213.323	3.33E-07	0.071	1.4E-02	1.0	6.0E-03	0.01	
235 U	.2	0.4275	2.14E-06	0.000914	1.4E-02	1.0	6.0E-03	0.01	
U Total	100%	213.75							
				1.828+03					1.535E-03

Table B-22. Beyond-Design-Basis Earthquake

Location	Inventory kg	Material at Risk (MAR) kg	Dispersibility Properties	Physical Form	Containment	Material	Isotope Weight %	Specific Activity (Ci/g)	Leak Path Factor (LPF)	Damage Ratio (DR)	Airborne Release Fraction (ARF)	Respirable Fraction (RF)	Source Term (g)mix
Granulating Process	118.1 kg	118.1 kg	Insoluble, ranging from respirable to non-respirable, generally dispersible	Granulate	Vessel	MOX	236Pu ∠ 1ppb 238 Pu 0.03 239 Pu 92.2 240 Pu 6.46 241 Pu 0.05 242 Pu 0.10 241 Am 0.90 238 U/D 99.8 235 U 0.2	533.86 17.8 0.0616 0.227 113.00 0.00391 3.240 3.33E-07 2.14E-06	1.0	1.0	ARF/RF =	8.6E-05	0.51[c]
Pelleting Process	112.5 kg	112.5 kg	Insoluble, non-respirable, nondispersible	Pellets	Press	MOX	236Pu ∠ 1ppb 238 Pu 0.03 239 Pu 92.2 240 Pu 6.46 241 Pu 0.05 242 Pu 0.10 241 Am 0.90 238 U/D 99.8 235 U 0.2	533.86 17.8 0.0616 0.227 113.00 0.00391 3.240 3.33E-07 2.14E-06	1.0	1.0	ARF/RF =	8.6E-05	0.48[c]
Boat Loading	111.7 kg	111.7 kg	Insoluble, non-respirable, nondispersible	Pellets	Boat	MOX	236Pu ∠ 1ppb 238 Pu 0.03 239 Pu 92.2 240 Pu 6.46 241 Pu 0.05 242 Pu 0.10 241 Am 0.90 238 U/D 99.8 235 U 0.2	533.86 17.8 0.0616 0.227 113.00 0.00391 3.240 3.33E-07 2.14E-06	1.0	1.0	ARF/RF =	8.6E-05	0.48[c]
Green Pellet Storage	261 kg	261 kg	Insoluble, non-respirable, nondispersible	Pellets	Boat	MOX	236Pu ∠ 1ppb 238 Pu 0.03 239 Pu 92.2 240 Pu 6.46 241 Pu 0.05 242 Pu 0.10 241 Am 0.90 238 U/D 99.8 235 U 0.2	533.86 17.8 0.0616 0.227 113.00 0.00391 3.240 3.33E-07 2.14E-06	1.00	1.0	ARF/RF =	8.6E-05	1.12[c]
Sintering and Storage	111.7 kg 607.5 kg	111.7 kg 607.5 kg	Insoluble, non-respirable, nondispersible	Pellets	Furnace Boat	MOX	236Pu ∠ 1ppb 238 Pu 0.03 239 Pu 92.2 240 Pu 6.46 241 Pu 0.05 242 Pu 0.10 241 Am 0.90 238 U/D 99.8 235 U 0.2	533.86 17.8 0.0616 0.227 113.00 0.00391 3.240 3.33E-07 2.14E-06	1.0	1.0	ARF/RF =	8.6E-05	048[c] 2.6
Fuel Rod Loading	101.1 kg in 22.46 trays	4.5 kg per tray	Insoluble, nonrespirable, nondispersible	Pellets	Trays	MOX	236Pu ∠ 1ppb 238 Pu 0.03 239 Pu 92.2 240 Pu 6.46 241 Pu 0.05 242 Pu 0.10 241 Am 0.90 238 U/D 99.8 235 U 0.2	533.86 17.8 0.0616 0.227 113.00 0.00391 3.240 3.33E-07 2.14E-06	1.0	1.0	ARF/RF =	8.6E-05	0.43[c]

Table B-22 Beyond-Design-Basis Earthquake (cont.)

Location	Inventory kg	Material at Risk (MAR) kg	Dispersibility Properties	Physical Form	Containment	Material	Isotope Weight %	Specific Activity (Ci/g)	Leak Path Factor (LPF)	Damage Ratio (DR)	Airborne Release Fraction (ARF)	Respirable Fraction (RF)	Source Term (g)mix
Fuel Rod Storage	4,400 rods 15,840 kg	None	Insoluble, nonrespirable, nondispersible	Fuel rods	Channel	MOX	236Pu ∠1ppb 238 Pu 0.03 239 Pu 92.2 240 Pu 6.46 241 Pu 0.05 242 Pu 0.10 241 Am 0.90 238 U/D 99.8 235 U 0.2	533.86 17.8 0.0616 0.227 113.00 0.00391 3.240 3.33E-07 2.14E-06	N/A	0.00	N/A	N/A	0.00
Fuel Shipment Loading	288 kg	None	Insoluble, nonrespirable, dispersible	Fuel assemblies	Containers	MOX	236Pu ∠1ppb 238 Pu 0.03 239 Pu 92.2 240 Pu 6.46 241 Pu 0.05 242 Pu 0.10 241 Am 0.90 238 U/D 99.8 235 U 0.2	533.86 17.8 0.0616 0.227 113.00 0.00391 3.240 3.33E-07 2.14E-06	N/A	0.00	N/A	N/A	0.00
Clean Scrap Recovery Area	17.25 kg	17.25 kg	Insoluble, ranging from respirable to nonrespirable, generally dispersible	Powder fine and grinder	Vessel	MOX	236Pu ∠1ppb 238 Pu 0.03 239 Pu 92.2 240 Pu 6.46 241 Pu 0.05 242 Pu 0.10 241 Am 0.90 238 U/D 99.8 235 U 0.2	533.86 17.8 0.0616 0.227 113.00 0.00391 3.240 3.33E-07 2.14E-06	1.0	0.5 0.5	1.0E-03 ARF/RF=	0.3 8.6E-05	0.13[b] 3.7E02[c]
Dirty Scrap Area	0.55 kg	0.55 kg	Insoluble, ranging from respirable to nonrespirable, generally dispersible	Powder, fine and grinder	Containers	MOX	236Pu ∠1ppb 238 Pu 0.03 239 Pu 92.2 240 Pu 6.46 241 Pu 0.05 242 Pu 0.10 241 Am 0.90 238 U/D 99.8 235 U 0.2	533.86 17.8 0.0616 0.227 113.00 0.00391 3.240 3.33E-07 2.14E-06	1.0	0.5 0.5	1.0E-03 ARF/RF=	0.3 8.6E-05	4.1.0E-03[b] 1.12E-03[c]
Analytical Services	0.008 kg	0.008	Insoluble, dispersible, respirable	Powder fine, solutions	Sample Vessel	MOX, Pu, U	236Pu ∠1ppb 238 Pu 0.03 239 Pu 92.2 240 Pu 6.46 241 Pu 0.05 242 Pu 0.10 241 Am 0.90 238 U/D 99.8 235 U 0.2	533.86 17.8 0.0616 0.227 113.00 0.00391 3.240 3.33E-07 2.14E-06	1.0	0.5 0.5	1.0E-03 ARF/RF=	0.3 8.6E-05	6.0E-05[b] 1.72E-05[c]

[a]The material balance is based on the referenced plant 200-MT MOX/yr scaled to a 100-MT MOX /yr plant (Refs. B-3, B-5, and B-10).
[b]Reference B-13, section 4.4.3.3.2, page 4-85.
[c]Reference B-13, section 4.3.3, pg. 4-52 (density =10.96 g/cm, h = 400 cm).
[d]MOX in processing storage vault: 1/3 MOX powder, 1/3 green pellets, and 1/3 sintered pellets.

B.12. REFERENCES

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B-4. BNWL-1697, "Considerations in Assessment of Consequences of Effluents from Mixed Oxides Fuel Fabrication Plants," Revision 1, June 1975.

B-5. PNL-2286-UC11, "Description of Reference LWR Facilities for Analysis of Nuclear Fuel Cycles," September 1979.

B-6. DOE, "Feasibility Assessment of Candidate DOE Sites And Building for a MixedOxide (MOX) Fuel Fabrication Facility For Disposed of Excess Weapon-Usable Plutonium," December 1996.

B-7. NUREG-1320, "Nuclear Fuel Cycle Facility Accident Analysis Handbook," May 1988.

B-8. NUREG-118, "Environmental Assessment for Renewal of Special Nuclear Material License No. SNM-1107," Docket No. 70-1151, Westinghouse Electric Corporation Nuclear Fuel Fabrication Plant, May 1985.

B-9. "NATO Advanced Research Workshop Mixed Oxide (MOX) Fuel, Commercial MOX Fuel Fabrication and Irradiation Experience in Belgium," October 12, 1994.

B-10. "Environmental Report, Westinghouse Recycle Fuels Plant," July 1973.

B-11. Regulatory Guide 3.35, "Assumptions Used for Evaluating the Potential Radiological Consequences of Accidental Nuclear Criticality in a Plutonium Processing and Fuel Fabrication Plant," US Nuclear Regulatory Commission, Washington, DC, May 1977.

B-12. DOE -STD-3009-94, "Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Safety Analysis Report."

B-13. DOE-HDBK3010-94, "Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities."

APPENDIX C
GENERIC MOX FACILITY REQUIREMENTS

This appendix addresses the generic requirements for a MOX FFF.

C.1. SITE

a. DOE site (limited to Hanford, INEEL, Pantex, or SRS by previous analysis)
b. Secure area and proper setbacks (1 mile desired unless in existing complex)
c. MOX Fuel Fabrication Facility or Building (MOX building (MB) - described below)
d. Security (site and MB)
e. Medical/emergency medical
f. Training
g. Administrative offices (MOX mission support: - e.g., engineering, utility coordination, material control, training, personnel, scheduling, security, large meeting room, training area mock ups)
h. Warehouse Space
i. Fire department
j. Maintenance facilities
k. Personnel facilities (badging, orientation, etc.)
l. Parking (MB and for construction/overhaul periods)

C.2. MOX BUILDING

The DOE-Material Disposition MOX mission may be implemented by the conversion of an existing facility or by the construction of a new facility. This section describes a new facility; however, it should be noted that a converted facility would need to provide the same overall functions. The generic MB is a reinforced concrete, two-story building designed to withstand integrity challenges from external hazards (tornado, blizzard, flood, earthquake, etc.) as well as to provide a safe and secure environment in which to manufacturer MOX fuel. Features are added to the structure to create what is referred to as a "hardened" structure (e.g., protective labyrinths at entrance/exit doors to act as penetration shields, protected ventilation penetrations, etc.). The hardened building houses all of the UO_2, PuO_2, fuel pellet, enriched UO_2 fuel pin (rod), and fuel bundle fabrication processes and fuel bundle storage areas. The building is maintained at slightly less than atmospheric pressure to contain any material leakage (gas, dusts, fumes, etc.) from the building areas. Exhaust gas from the building is processed through twin train (one in standby), triple HEPA filters before it is released up a redundantly monitored stack. PuO_2 fuel pellet fabrication areas are maintained at the lowest pressure. Several different MB HVAC systems are used to establish building space pressure differentials so that air (in-leakage) moves from the areas of lowest potential contamination to the areas of highest potential contamination. The building control room has its own dual, independent HVAC systems. The basement level of the building is intended to be below ground for seismic and accident reasons. The basement contains the PuO_2, DUO_2, UO2, enriched fuel pin, and fabricated fuel bundle storage vaults. Safe secure transport (SST) unloading (incoming oxides) and shipping (outgoing MOX fuel assemblies) docks are also in the basement. General material shipping and receiving docks and warehousing areas are in the basement. Building utilities and waste processing are in the basement portion of the MB (the basement provides a low point for gravity drains). MB general requirements are outlined below. Actual space and physical arrangements will vary with implementation; however, in general, all of the physical attributes required for MOX fabrication will be implemented in some capacity to fulfill the requirements *outlined below.*

Personnel

Entry and egress paths and emergency exits (one main exit, several alternate exits)
Reception area
Staff offices:

a. Plant manager
b. Engineering
c. Shift supervisor(s)
d. Maintenance supervisor(s)
e. Health physics supervisor
f. Material control
g. IAEA facilities
h. Shipping and receiving supervisor
I. NRC offices
j. visitor offices (minimum of four recommended)

Conference rooms (project coordination/meeting rooms - minimum 4 recommended)
Personnel protective equipment (personnel protective equipment (e.g. anti-c's, gloves, boots, etc.) change out, emergency decontamination, equipment storage, equipment cleaning/storage)
Break area (e.g., vending, lunch tables)
Locker rooms and personal areas
Repair areas

Auxiliaries

Electrical rooms (two separate incoming power sources, facility distribution 480 and 208/120, two standby generators and related switch gear - note all critical loads are envisioned to be on UPS systems with interim "ride through" capability, e.g., 5-10 min.)
HVAC Rooms (MOX area - two trains, fuel fabrication areas, storage area, personnel areas, shipping areas, control room, etc.)
Fire protection equipment rooms
Communications room (phone, page, radio, internet)
Plumbing

Liquid waste drains system, sumps
Liquid rad waste collection system
Security system equipment room
Radiation protection monitoring (ARM, criticality, ventilation system alarm monitoring) equipment room/areas
Fire detection and monitoring
Standby generators (2)
Gas storage facilities (argon, helium, hydrogen)
Building exhaust stack

<u>MOX Material Receiving and Storage (PuO_2, UO_2, DUO_2, fabricated fuel pins)</u>

Safe secure transport dock
Material receipt area (including fork lift parking)
Material inspection area(s)
Material accountability area(s)
Material storage areas:
- PuO_2 vault
- UO_2 and DUO_2 vault
- Fuel pins vault

Material accountability/transfer to production areas
Material accountability office
IAEA office

<u>Fuel Assembly and Production Materials Receiving</u> (Non SNM Material which includes additives, personnel protective equipment (PPE), administration supplies, fuel pins, fuel bundle components, etc.)
Truck Bays (two - tractor-trailer docks) also may be used by UPS, FEDEX, USPS, etc. unless alternate delivery arrangements are established (note that delivery inside the PIDAS will be required for a number of shipments, and it is assumed that security force personnel will accompany delivery vehicles under these circumstances).
Material Receipt Area (including forklift parking)
Material Inspection Areas
Material Accountability (Fuel bundle components - incoming)
Material Storage Areas:
- Administrative supplies (paper, building cleaners, forms, etc.)
- PPE storage (anti-c's, masks, filters, gloves, boots, etc.)
- Fuel bundle component storage
  - segregated (BWR, PWR, Other)

Material accountability/transfer to production areas
Spare parts storage

<u>MOX Production</u>

PPE change room(s) (need two for alternate exits, main and auxiliary)
Locker area with male/female areas and showers
Analytical laboratory

Health physics laboratory
Emergency decontamination equipment
Air locks and passage ways (dual exits)
Automation computer/programmable logic controllers conditioned space
Material accountability control point
Three MOX Lines or other equivalent arrangement (two installed, space for third, as appropriate)

Per Line

Material staging - Note: off-line storage at each position listed below
Preblend mix (master blend)
Material accountability/quality control
PuO_2 concentration blend
Material accountability/quality control
Additive blend and final grind
Material accountability/quality control
Pellet press
Material accountability/quality control
Sintering oven (furnace)
Material accountability/quality control
Final conformance grind and pellet inspection
Material accountability/quality control
Pellet classification and storage
Material accountability/quality control
Recycle material
Material accountability/quality control
Offgas treatment system
Gas storage and supply (note that certain tanks such as the H_2 tank will be located separate but adjacent to the MOX building)
Waste treatment/handling
Waste storage and load out
Dirty waste storage
Scrap recovery

HVAC facilities (separate one system per line)
HVAC facilities (common passage areas)
HVAC facilities (HP area and laboratories)
HVAC facilities (change rooms)
Personnel access checkpoints/control
Offgas stack system

Fuel Pin and Bundle Fabrication

Receipt inspection
Material accountability/quality control

Material storage:
- Segregated by fuel type (BWR or PWR or Other):
  - Fuel pins
  - Spacers
  - End plates
  - End plugs
  - Additives
  - Binders. pore formers
  - Lubricants
  - Misc. components

Material accountability/quality control
Material staging and inspection (prior to actual fabrication)
Material accountability/quality control
Weld end plugs and inspect
Material accountability/quality control
Fuel pin loading
- Three lines (one for BWR, one for PWR, and one for other)
- Material staging
- Pin clean/inspection
- Weld end plug
- Weld quality control
- Pin staging
- Material accountability/quality control
- UO_2 pellet staging
- PuO_2 pellet staging
- UO_2 enriched pin staging
- Pin outgassing
- Gas fill (helium)
- Pin loading
- Weld end plug
- Pin inspection
- Material accountability/quality control
- Loaded pin staging
- Fuel bundle parts staging
- Bundle assembly
- Material accountability/quality control
- Bundle inspection
- Material accountability/quality control
- Bundle storage

<u>Fuel Bundle Shipping</u>
- Shipping materials staging areas
- Material accountability/quality control
- Fuel bundle loading
- Shipping container inspection and staging for shipment
- Material accountability/quality control
- Loading area with forklift

Safe secure transport dock area

Material accountability/quality control
IAEA offices

Emergency Facilities
- Fire
- Medical
- Police